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Regulatory Impact Analysis of Final Environmental Standards for Uranium Mill Tailings at Active Sites

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The Environmental Protection Agency was directed by Congress, under PL 95-604, the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), to set standards of general application that provide protection from the hazards associated with uranium mill tailings. Title II of the Act requires standards covering the processing and disposal of byproduct materials at mills which are currently licensed by the appropriate regulatory authorities. This Regulatory Impact Analysis (RIA) addresses the standards promulgated under Title II. There are two major parts of the standards for active mills: standards for control of releases from tailings during processing operations and prior to final disposal, and standards for protection of the public health and environmenta after the disposal of tailings. This report presents a detailed analysis of standards for disposal only, since the analysis required for the standards during mill operations is very limited.

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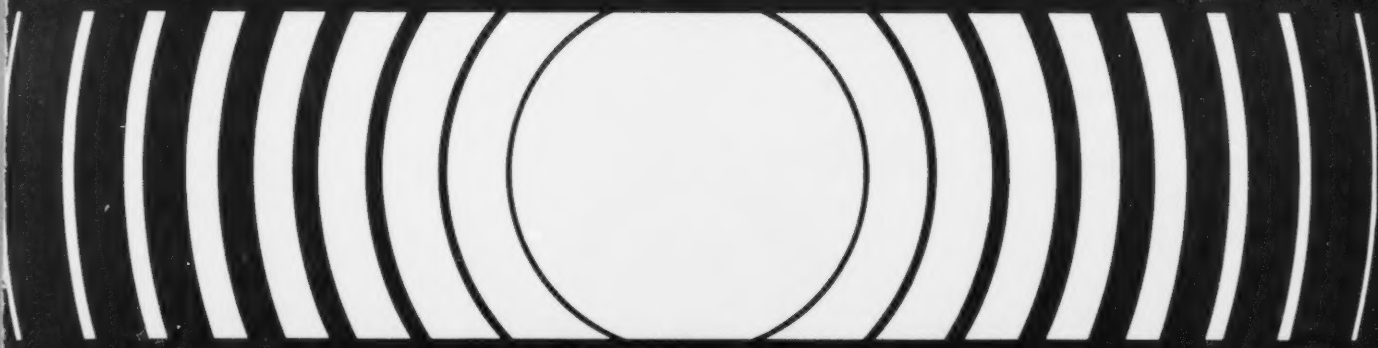

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SUMMARY

Background

The Environmental Protection Agency was directed by Congress, under PL 95-604, the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), to set standards of general application that provide protection from the hazards associated with uranium mill tailings. Title I of the Act pertains to tailings at inactive sites for which the Agency has developed standards as part of a separate rulemaking. Title II of the Act requires standards covering the processing and disposal of byproduct materials at mills which are currently licensed by the appropriate regulatory authorities. This Regulatory Impact Analysis (RIA) addresses the standards promulgated under Title II. On April 29, 1983, EPA proposed these standards, accompanied by a regulatory impact analysis of the proposed standards (EPA 520/1-82-023).

There are two major parts of the standards for active mills: standards for control of releases from tailings during processing operations and prior to final disposal, and standards for protection of the public health and environment after the disposal of tailings. This report presents a detailed analysis of standards for disposal only, since the analysis required for the standards during mill operations is very limited. The analysis for the operations standards is limited because most of the requirements reflected by these standards are already in existence through regulations established under the Atomic Energy Act (AEA), the Clean Water Act (CWA), and the Solid Waste Disposal Act (SWDA). Also, UMTRCA directs EPA to develop groundwater protection standards which are consistent with the standards promulgated under the SWDA, as amended. Consequently, there are very few regulatory alternatives to be considered in the development of standards for control of mill tailings during the operational phase of a mill. For completeness, the operations standards and an explanation of their basis are presented in this report along with the disposal standards. The reader should refer to the Final Environmental Impact Statement (FEIS) which accompanies the RIA for more information on the analysis of the operations standards.

Methodology

The analysis consists primarily of an examination of the overall benefits and costs associated with the disposal of uranium mill tailings. This analysis gives some indication of what level of control of the hazards is most cost-effective, but cannot, of itself, be used to determine the final standards. These must also address the maximum exposure of individuals and reflect the technical practicability of implementing undemonstrated technology for control over very long periods of time. An economic impact analysis which estimates the economic consequences of incurring the costs of alternative standards was also carried out to determine that the values chosen for standards could be reasonably imposed.

We performed separate benefit-cost analyses for existing tailings and new tailings piles to reflect differences between past and future practice, both of scale and of control methods. Since the standards are generally applicable technical performance and containment standards rather than engineering design standards, they do not specify particular methods of compliance. For analytical purposes, however, we determined disposal methods which correspond to each of the alternative standards. These methods assume different degrees of earthen cover and surface stabilization as the technique for providing long-term control. We estimated costs for these tailings disposal methods, conservatively, to account for uncertainties in design parameters, and performed the calculations on the basis of model piles. In the benefits analysis, the health effects averted by control of radon emanation from tailings piles is the only benefit we can quantify. We performed an analysis of the incremental cost per radon death avoided for the alternative standards to determine what level of control may be justified on the basis of benefit-cost analysis. Since this analysis only takes into account one of the benefits of tailings disposal, we developed an alternative analysis which incorporates all the benefit categories into a single measure. We developed an effectiveness index which rates each disposal method according to its effectiveness in providing four specified control classes: inhibition of misuse, radon control, prevention of the surface spread of tailings, and water protection. A cost-effectiveness analysis was then used to evaluate the incremental costs for each disposal method. Based on the analysis of the incremental cost per radon death avoided and the cost-effectiveness analysis, we selected candidate disposal standards which represent optimal levels of control. These were reduced to a final selection based on consideration of practicability and the feasibility of reducing risks to the maximum exposed individual. The determination of implementation requirements for the standards, such as the groundwater protection requirements at existing mills, was based on considerations beyond those addressed in the benefit-cost analysis and is discussed in Chapter 6.

Alternative Standards

Table S.1 lists 13 alternative standards which we have considered for the control of mill tailings after disposal. These alternative standards are stated in terms of a radon emission limit and/or a requirement for longevity of control. The combination of these two requirements will satisfy the objectives of misuse inhibition, radon control, prevention of surface spread of tailings, and water protection. The alternative standards range from no controls to substantial levels of control which approximate the achievement of basically the same environmental consequences as might occur if the uranium ore had not been mined. Five alternative radon emission limits were analyzed: no emission limit, 60 20, 6 and 2 pCi/m^{2}s. Three alternative longevity requirements were considered: active control of tailings for a period of 100 years, a 1000-year requirement for passive control, and the 1000-year requirement for passive control achieved together with improved radon control during mill operation for new tailings piles. Alternative standards B and C

Table S.1. Alternative Disposal Standards

Longevity Requirement	Radon Control after Disposal (pCi/m^2s)				
	No Radon Requirement	60	20	6	2
No Controls	A				
Active control for 100 years	B1	B2	B3		
Passive control for 1000 years	C1	C2	C3	C4	C5
Passive control for 1000 years, with improved radon control during operations for new piles		D2	D3	D4	D5

assume a uniform level of control for both existing and future tailings while Alternative D requires the additional control of radon during operation for new piles. Although this last requirement is directed toward the operating phase of a mill, the method of compliance (phased disposal) is a different disposal configuration from that assumed in Alternative C. Therefore, it is only applicable to new tailings piles which can design for such a requirement before tailings have already accumulated. Table S.2 summarizes the benefits of each alternative standard through the use of several quantitative and qualitative measures. Table S.3 presents the costs of each alternative, as well as the control method assumed for the cost estimation.

The chance for misuse of the tailings under each alternative standard is estimated to range from likely for Alternative B1 and C1 to very unlikely for Alternatives C4, C5, D4 and D5. For measuring the prevention of surface spread of tailings, we use the estimated time period over which erosion of the tailings by wind and water would be avoided. These estimates range from a hundred years for Alternative B1 to many thousands of years for Alternatives C4, C5, D4 and D5. For radon control, Alternatives B1 and C1 would reduce emissions by 50 percent from the uncontrolled state over the first 100 years after disposal, while Alternatives B2, C2, and D2 would result in an 80 percent reduction and Alternatives B3, C3, and D3 a 95 percent reduction. Alternatives C4 and D4 would provide a 98.5 percent reduction in radon emissions, while Alternatives C5 and D5 would have a reduction of 99.5 percent from the uncontrolled condition. For a period of 1000 years or greater, the percentage reductions in radon emissions for Alternative B1, B2 and B3 - the active maintenance methods - would be less than those stated above since after the maintenance stops, the effectiveness of the earthen cover is expected to decline. We estimate that the percentage reduction in radon emissions for these alternatives over a period of 1000 years will be 20, 30, and 35 percent, respectively. The radon deaths avoided by these controls and the maximum risk of lung cancer to individuals residing close to the piles which correspond to each alternative standard are shown in Table S.2. The additional benefit of radon control during mill operations for new piles is not included in this table for Alternative D. For water protection, we estimate that the alternative standards would provide a range of protection from 100 years duration for Alternative B1 to greater than 1,000 years for Alternatives C4, C5, D4, and D5.

The costs of the alternative standards in Table S.3 are segmented by two categories of tailings: existing tailings and future tailings. The future tailings are those which we estimate to be produced from 1983 through the year 2000 according to recent Department of Energy projections. A range in disposal costs for future tailings is presented for each alternative which represents different assumptions on the implementation of groundwater protection requirements during the operational phase of a mill. The lower cost estimate assumes that all future tailings at existing mills are added to existing impoundments and disposed of (covered) together. No corrective actions at existing piles for compliance with groundwater protection requirements are assumed. The

Table S.2. Summary of Benefits for Alternative Disposal Standards

	Stabilization		Radon Control				Water Protection
Alternative Standards	Chance of Misuse	Tailings Erosion Avoided (years)	Maximum Risk[a] of Lung Cancer (% reduction)	Deaths Avoided[b]			Longevity (years)
				First 100 years	1,000 years	Total	
A	Very likely	0	2 in 10^2(0)	0	0	0	0
B1	Likely	Hundred	1 in 10^2(50)	300	1200	1200	100
B2	Less Likely	Hundreds	4 in 10^3(80)	480	1800	1800	100
B3	Less Likely	Hundreds	1 in 10^3(95)	570	2100	2100	100
C1	Likely	Hundred	1 in 10^2(50)	300	3000	Thousands	100
C2	Less Likely	Thousands	4 in 10^3(80)	480	4800	Many 1000's	100's
C3	Unlikely	Thousands	1 in 10^3(95)	570	5700	Tens of 1000's	1000
C4	Very Unlikely	Many thousands	3 in 10^4(98.5)	590	5900	Tens of 1000's	>1000
C5	Very Unlikely	Many thousands	1 in 10^4(99.5)	600	6000	Tens of 1000's	>1000
D2	Unlikely	Thousands	4 in 10^3(80)	480	4800	Many 1000's	1000
D3	Unlikely	Many thousands	1 in 10^3(95)	570	5700	Tens of 1000's	1000
D4	Very unlikely	Many thousands	3 in 10^4(98.5)	590	5900	Tens of 1000's	>1000
D5	Very unlikely	Many thousands	1 in 10^4(99.5)	600	6000	Tens of 1000's	>1000

[a] Lifetime risk of fatal cancer to an individual assumed to be living 600 meters from the center of a model tailings pile. The estimates of benefits assume no credit for engineering factors required to provide "reasonable assurance" of design compliance for the specified radon control level and period of longevity.

[b] These estimates pertain to the control of 26 existing piles and 9 projected new pile equivalents. Of the approximately 600 deaths which are estimated to occur in the first 100 years under no control conditions, about 500 are the result of the existing tailings and 100 are due to future tailings.

Source: Table 4.5 and Chapter 10 of the FEIS.

Table S.3. Summary of Costs for Alternative Disposal Standards
(millions of 1983 dollars)

Alternative Standard	Assumed Control Method	Cover Thickness (meters)	Industry Costs, Undiscounted			Present Worth Costs (10% discount rate)
			Existing Tailings	Future Tailings	Total	
A	No control	-	0	4	4	1
B1	Above-grade, 3:1 slope, irrigation and maintenance for 100 years	0.5	155	84-474	239-629	141-319
B2		1.5	253	98-549	351-802	219-424
B3		2.4	338	114-632	452-970	288-524
C1	Above-grade, 5:1 slope, rock cover on slopes, 0.5 m of pebbly soil on top of pile	0.5	152	124-474	276-626	157-316
C2		1.5	253	145-570	398-823	240-433
C3		2.4	343	165-653	508-996	314-537
C4		3.4	443	186-744	629-1187	397-651
C5		4.3	532	215-829	747-1361	474-755
D2	Same as C for existing piles and staged disposal below-grade for new piles	1.5	253	184-837	437-1090	249-546
D3		2.4	343	201-906	544-1249	323-644
D4		3.4	443	221-989	664-1432	406-755
D5		4.3	532	252-1065	784-1597	483-855

Source: Table 4.3 and Table 5.7.

higher cost estimate assumes that all future tailings at existing mills are placed in new impoundments equipped with liners for groundwater protection and disposed of separately from the existing piles. We believe that the total cost for the industry will most likely fall within this range.

Final Standards

Operations Standards

In accordance with the Act, the operations standards for primary groundwater protection require that tailings impoundments be designed to prevent seepage of leachate from tailings into groundwater. The secondary groundwater standards are based on the monitoring and response concept, consistent with SWDA, as amended. Nondegradation standards for groundwater are for hazardous constituents that are in or can be derived from tailings, except for a short list of toxic materials for which concentration limits are specified. In addition to the list of hazardous constituents specified under SWDA standards, the standards add two hazardous elements commonly found in tailings: molybdenum and uranium. Concentration limits are also added for alpha radioactivity. If background levels or concentration limits are exceeded, a corrective action program consistent with SWDA, as amended, must be initiated as approved by the regulatory agency.

Existing standards and regulations for control of radionuclide particulate emissions to air under the AEA (40 CFR Part 190) and effluents to surface water under the CWA (40 CFR Part 440) for uranium mill tailings are not changed by these final standards. Radon emissions from uranium mill tailings during the operational phase of a mill are currently controlled by general NRC regulations (10 CFR Part 20) derived from Federal Radiation Protection Guidance and are not changed by these standards. However, an Advanced Notice of Proposed Rulemaking is being prepared to solicit and collect information for the Agency to consider further the control of radon during operation of tailings impoundments.

Disposal Standards

Based on the benefit-cost analysis of control methods, plus consideration of the technical practicability of implementing undemonstrated technology and the feasibility of reducing risks to maximum exposed individuals, we have chosen Alternative Standard C3 for the disposal standard. The standard requires that control of uranium byproduct materials be designed to provide reasonable assurance that they will be effective for 1000 years and that releases of radon-222 to the atmosphere will not exceed an average rate of 20 picocuries per square meter per second. The standard requires control of hazardous waste constituents listed under 40 CFR Part 261 to prevent their escape to ground or surface waters or to the atmosphere to the extent necessary to protect human health and the environment. Also, disposal of uranium mill tailings shall be done in a manner which minimizes the need for further maintenance.

Benefits of Standards

Under the standards, the tailings would remain covered and isolated for 1,000 years or more. Therefore, we believe that the possibility of the misuse of most tailings will be unlikely for many thousands of years. Radon emissions from the disposed tailings will be significantly reduced from what they would be in an uncontrolled state. We estimate that the total deaths avoided by radon control alone would be several thousand during the first thousand years, compared to tailings which are left uncontrolled, and many tens of thousands over the entire useful life of the controls. The health risk to people living very near the tailings piles will be reduced from about 2 chances in 100 of fatal lung cancer during their lifetime to about 1 chance in 1,000. Also, it is estimated groundwater would be protected for thousands of years under the standards. Finally, the possibility of contamination of land by erosion of tailings would be virtually eliminated for many thousands of years.

Cost and Economic Impacts of Standards

We estimate that compliance with the standards, if other regulatory requirements did not exist, would cost the uranium milling industry from about 310 million to 540 million dollars to dispose of all tailings which exist today at licensed sites, as well as those which we estimate will be generated by the year 2000. These costs are present worth estimates (discounted at a 10% rate) expressed on a 1983 constant dollar basis. The range in cost is due to different assumptions on the implications of the requirement for groundwater protection for future tailings at existing mills.

We estimate that the average uranium price may increase from 2 to 7 percent. In light of the currently poor economic condition of the industry and the threat of foreign competition, it is unlikely that mills will be able to pass through substantial portions of the disposal costs to their customers. Based on our model mill closure analysis which was performed under a variety of cost pass-through and cash-flow conditions, we estimate that no mills will cease operation due to control of tailings.

These costs are not incremental costs of the standards, since much of this cost would probably occur in the absence of the standards due to other regulatory requirements. These other requirements are Nuclear Regulatory Commission (NRC) licensing regulations and State regulations, and regulations required under Section 84(a)(1) and (3) of UMTRCA. We did not estimate the costs imposed by these other regulations in part because that would require a site-specific investigation. Since our standards are required by Congress to be of general application, we decided to develop a generic analysis based on model facilities. Therefore, we could not estimate the net impact of the standards.

Regulatory Flexibility Analysis

The standards would not have a significant impact on a substantial number of small entities, as specified under Section 605 of the Regulatory Flexibility Act (RFA). Therefore, we have not performed a Regulatory Flexibility Analysis. The basis for this finding is that of the 27 licensed uranium mills, only one qualifies as a small entity, and this mill will not be impacted by the standards. Almost all the mills are owned by large corporations. Three of the mills are partly-owned by companies that could qualify as small businesses, according to the Small Business Administration generic small entity definition of 500 employees. However, according to the RFA, a small business is one that is independently owned and operated. Since these three mills are not independently owned by small businesses, they are not small entities. The Regulatory Flexibility Act certification is presented in Appendix D of this RIA.

1. Introduction

The existence of large quantities of uranium mill tailings at uranium mill processing sites poses a significant hazard to health. Tailings are hazardous because: (1) breathing radon and its decay products exposes the lungs to alpha particles; (2) breathing particulates of thorium, uranium, and their decay products exposes the lungs to alpha particles; (3) the body may be exposed to gamma rays; (4) radioactive materials and nonradioactive toxic elements from byproduct material may be swallowed with food and water. Since the radioactivity from these materials lasts for hundreds of thousands of years, the cumulative effects of tailings may be large. Detailed assessments of the hazards associated with human exposure to tailings are presented in the FEIS. This RIA draws on those results for its quantitative assessment of the benefits of control of tailings.

Congress recognized this problem when it passed PL 95-604, the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA): "The Congress finds that uranium mill tailings located at active and inactive mill operations may pose a potential and significant radiation health hazard to the public....and that every reasonable effort should be made to provide for the stabilization, disposal, and control in a safe and environmentally sound manner of such tailings." The Environmental Protection Agency was directed to set standards of general application which provide protection from the hazards associated with both the mill tailings at designated inactive sites of milling operations (Title I) and the processing and disposal of byproduct material at presently licensed and future mills (Title II). This RIA addresses only the standards developed under Title II. The standards for inactive mill sites have been previously issued by the Agency.

Scope of Standards

There are two major parts of these standards: control of releases from tailings during processing operations and protection from the tailings after disposal. However, this RIA addresses the standards for tailings disposal only. This is because most of the requirements reflected by the operations standards are already in existence through regulations established under the Atomic Energy Act, the Clean Water Act, and UMTRCA itself. Consequently, there are very few regulatory alternatives to be considered in the development of standards for control of mill tailings during the operational phase of a mill.

During mill operations all radioactive effluents are regulated under the Environmental Radiation Protection Requirements for Normal Operations in the Uranium Fuel Cycle (40 CFR 190) except radon emissions. These standards, which apply during processing operations only, were published on January 13, 1977, and became effective for uranium mills and byproduct material on December 1, 1980. However, radon was excluded because of insufficient knowledge at the time 40 CFR 190 was established. EPA is considering requiring control of radon emissions during mill operations under the Clean Air Act (CAA). An Advanced Notice of Proposed Rulemaking is being prepared to solicit and collect information for the Agency to consider further the control of radon from tailings piles during the operational period of a mill.

During the operational phase of a uranium mill, discharges of process wastewater are controlled under the Clean Water Act. Currently, the regulations (40 CFR Part 440) require the use of best practicable technology (BPT) for the control of effluents from uranium mills. Rules were promulgated on December 3, 1982 (47 FR 54598, 40 CFR Part 440, Subpart C), to provide BPT effluent limitations and to establish new source performance standards (NSPS) under the Clean Water Act. These NSPS rules specify that there shall be no discharge of process wastewater from uranium mills in arid areas.

As required by UMTRCA, protection of groundwater from hazardous materials in uranium tailings is to be provided by standards which are consistent with standards required under subtitle C of the Solid Waste Disposal Act (SWDA), as amended. EPA promulgated standards applicable to owners and operators of hazardous waste treatment, storage, and disposal facilities on July 26, 1982 (47 FR 32274, 40 CFR Part 261, Subpart F). These same SWDA standards, supplemented by a few additions at comparable levels of control for materials specific to uranium byproduct materials, are proposed in these standards. We also note that, independent of these proposed standards, UMTRCA also requires the Nuclear Regulatory Commission (NRC) to implement the SWDA standards for groundwater protection in their licensing requirements for uranium mills. Consequently, uranium mills must comply with the SWDA groundwater protection standards even in the absence of these standards.

Need for Standards

In recognition of the Agency's guidelines for preparing a regulatory impact analysis, we discuss why we believe there is a need for the standards beyond the fact that Congress directed us to do so. There is a definite need for government intervention to mitigate this potential health hazard since there is no market mechanism which would provide health protection to the public. Disposal of mill tailings is not a revenue-producing activity because the mill tailings are essentially a waste product and have no value (although there is some small possibility for mineral recoverability). In addition to the absence of market forces to correct this problem, the lack of government control has increased the potential for adverse health effects to occur. In the past, members of the public not aware of the hazardous nature of tailings have hauled them away from inactive mill sites for use as a construction material for their homes. This greatly increases the health risk from the tailings from what it would be if the tailings were left untouched. We conclude that there is a need for government intervention to protect the public from the hazards associated with the existing tailings inventory and from future tailings generation.

Historically, there was little Federal regulatory control of uranium mill tailings until the mid-1970's. Control of tailings was not included in the original licensing procedures for uranium mills by the NRC (formerly the Atomic Energy Commission) because the tailings were not known to be hazardous and were not a controllable material under the AEA. With the passage of UMTRCA, Congress included uranium mill tailings under the AEA, instructed EPA to develop generally applicable standards for control of mill tailings, and directed NRC to incorporate the EPA standards into their uranium mill licensing requirements. On October 3, 1980, NRC published final regulations for mill tailings disposal despite the absence of proposed EPA standards (45 FR 65521). In the preamble to their regulations, NRC recognized that their rules must be compatible with the EPA standards and stated that their "regulations will be revised, if required, when EPA standards are issued."

Currently licensed mills are located in seven States. Four of the States - Colorado, New Mexico, Texas, and Washington - are NRC Agreement States and have developed their own licensing regulations for uranium mills. These State regulations include the management of uranium mill tailings. Mills in the other three states - Utah, Wyoming, and South Dakota - are licensed by NRC directly. These two State groupings each represent about one-half of the total industry production. Consequently, there is a need for Federal intervention since relying on State regulations would only address one-half of the problem. Furthermore, the Act requires that regulations for mill tailings developed by the Agreement States should be "equivalent, to the extent practicable, or more stringent than standards" promulgated by NRC and EPA. Therefore, the State regulations are also dependent on the EPA standards.

Content of this RIA

In developing the regulatory options for this RIA, we have proceeded as if the NRC regulations had not been issued. The NRC rules emphasize requirements that a new mill must meet, but they state that regulations for existing sites cannot be developed in a generic fashion but must be considered on a site-by-site basis. In formulating the EPA regulatory options, we have segmented the uranium milling industry into existing and new mills and have examined the benefits, costs, and economic impacts of alternative levels of control on each segment.

In Chapter 2 of this RIA, we present a profile of the uranium milling industry and a characterization of the existing mill tailings inventory. Chapter 3 discusses the objectives of the standard and the alternative ways to achieve them. Chapter 4 presents a benefit-cost analysis of alternative disposal standards for existing and new tailings piles, on a model pile basis. Chapter 5 presents the industry cost and economic impact analysis of several combinations of disposal methods. Chapter 6 presents the rationale for choosing the standards. Supporting documentation and data displays are contained in the Appendices.

This RIA contains all of the elements set forth in the Office of Management and Budget guidelines of June 5, 1981, for conformance with Executive Order 12291.

2. Industry Profile

This chapter develops background information on the structure and economic condition of the uranium mining and milling industry. The profile includes both historical and current data which form the foundation for the economic impact analysis. Projections of industry price, demand, and supply are developed in Appendix B.

The uranium industry is characterized by a relatively high degree of concentration with major publicly held corporations accounting for a large share of ownership in the industry. The industry experienced rapid growth in the early and mid-1970's that was stimulated by expectations of large increases in demand. The expectations of growth in demand proved to be too optimistic leading to supply outstripping demand and resulting in an economic slump for the industry. The industry is presently faced with excess capacity, large inventories, lower than expected demand, greatly reduced spot prices, and increased competition from imports. In response to this situation, there is currently a significant amount of consolidation activity in the industry (NU83). There are some producers who are aggressively expanding their uranium holdings, while there are others who are leaving the business by disposing of properties or closing production facilities.

2.1 Demand

2.1.1 The Nuclear Fuel Cycle

The uranium mining and milling industry is only one component of a much larger industry. The operations required to provide nuclear fuel for and to dispose of wastes from light water nuclear power reactors (LWRs) constitute the bulk of the U.S. nuclear fuel cycle. The various segments of the LWR nuclear fuel cycle are:

- Uranium mining and milling
- UF_6 conversion
- Isotopic enrichment
- UO_2 fuel fabrication
- Interim storage and transportation of spent fuel
- Disposal of spent fuel, or recovery of fissile material from spent fuel.

If the fissile fuel values are recovered, three additional fuel cycle segments are present. These are:

- Reprocessing
- Mixed oxide fuel fabrication
- Disposal of reprocessing and mixed oxide fuel fabrication wastes.

A schematic representation of the LWR fuel cycle is shown in Figure 2.1.

The generation of nuclear-powered electricity is the only major commercial source of demand for uranium in the United States, accounting for approximately 98 percent of total demand. Depleted uranium, a byproduct of the enrichment of natural uranium, is used in ordnance (military weaponry), for radiation shields, and in research. The supply of this byproduct greatly exceeds demand.

There are no substitutes for uranium in the production of nuclear energy by LWRs, although plutonium is a supplement. Lead, tungsten, and other heavy metals can replace uranium in nonnuclear applications.

Historical uranium concentrate production figures given in Table 2.1 show that the uranium industry had several periods of expansion and contraction. The U.S. Atomic Energy Commission (AEC) encouraged an expansion of the uranium industry following World War II by purchasing raw ore, and later yellowcake, building access roads and offering special incentives (Ta79). The expansion ended in the early 1960's when the AEC reduced purchases because U.S. military needs had been satisfied. The second major expansion began in the mid-1970's when confidence in the future of nuclear power was high and uranium prices had begun to climb. Production in 1980 reached nearly 20,000 metric tons of U_3O_8, an increase of 90 percent from the 1975 level of 10,500 metric tons.

Electricity generated by utilities supplies approximately 13 percent of the nation's total energy needs, while nuclear power plants supply about 12 percent of the nation's electricity (Ev83). Electricity demand has grown slowly since the oil embargo in 1973. Since 1979, the annual growth rate has remained below 2 percent and has declined steadily, whereas the pre-embargo growth rate averaged about 7 percent per year (DOE83a). The slowdown in demand may be attributed to increases in the price of electricity due to higher fossil fuel and capital costs and resulting conservation efforts.

Since there are no substitutes for uranium in the generation of nuclear-powered electricity, a continuing demand for uranium is expected. However, the rate of growth in future demand is unclear. Table 2.2 shows the number of nuclear plants ordered each year from 1966 through 1982. After 1973, the number of orders has fallen dramatically, from 38 in 1973 to two in 1978, and none since. Additionally, about 40 percent of the total orders placed, representing 45 percent of capacity, has been cancelled as of December 31, 1982. The annual cancellations of these orders are also shown in Table 2.2. In 1982 alone, 18 units were cancelled. Also, many reactor projects have been significantly delayed. Currently, there are 76 nuclear power reactors licensed to operate in the U.S., and about 11 plants should begin operations in the next two years (DOE Midcase projection) if the licensing process is not delayed (Di83).

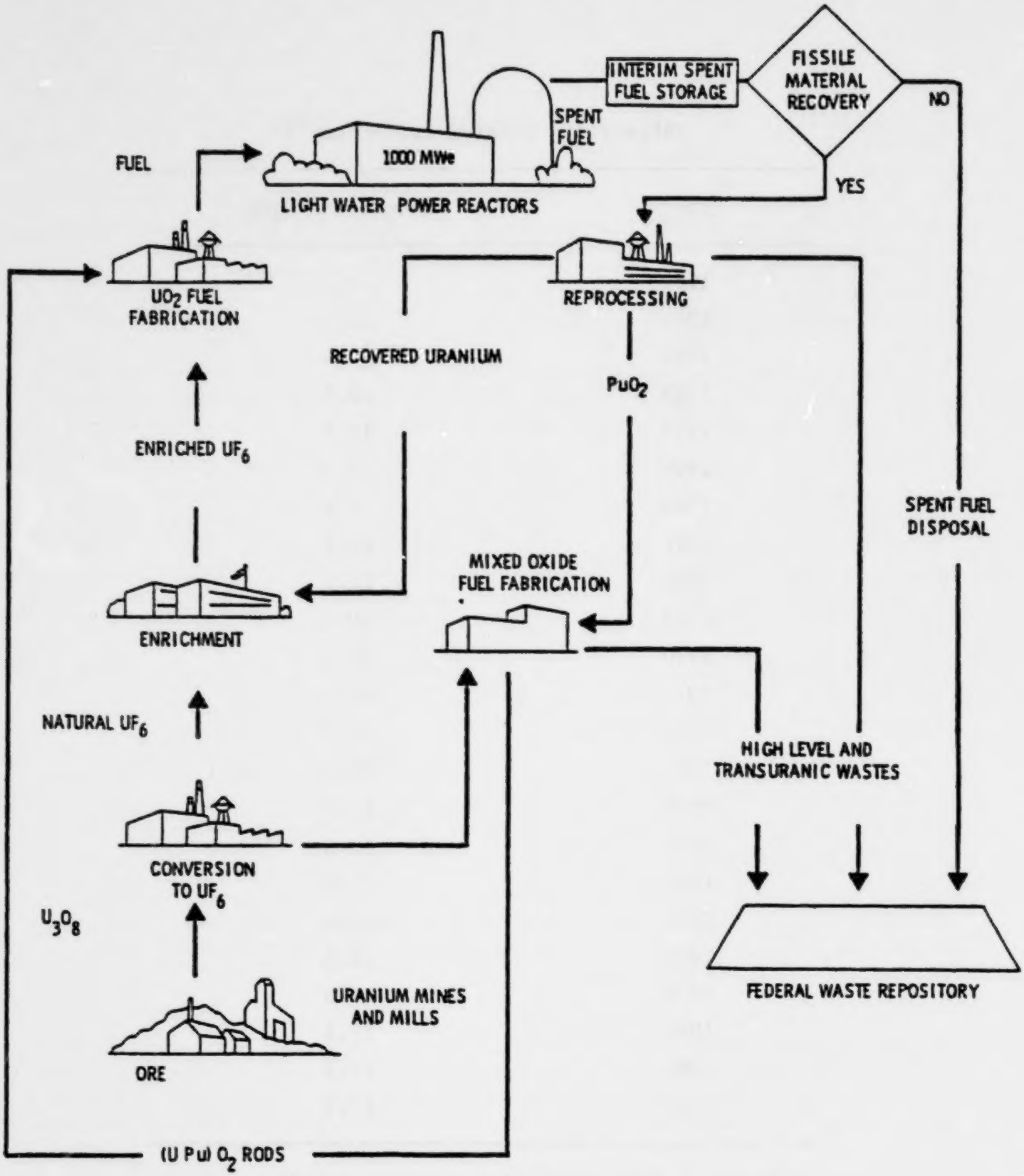
INTERIM SPENT FUEL STORAGE
FISSILE MATERIAL RECOVERY
NO
YES
SPENT FUEL
1000 MWe
FUEL
LIGHT WATER POWER REACTORS
UO2 FUEL FABRICATION
REPROCESSING
RECOVERED URANIUM
PuO2
ENRICHED UF6
SPENT FUEL DISPOSAL
MIXED OXIDE FUEL FABRICATION
ENRICHMENT
NATURAL UF6
HIGH LEVEL AND TRANSURANIC WASTES
CONVERSION TO UF6
U3O8
FEDERAL WASTE REPOSITORY
URANIUM MINES AND MILLS
ORE
(U Pu) O2 RODS

Figure 2.1. Light Water Reactor Fuel Cycle

Source: Battelle Pacific Northwest Laboratory, Fuel Cycle Cost Projections, prepared for U.S. Nuclear Regulatory Commission, NUREG/CR-1041, December 1979.

Table 2.1. Uranium Production[a]

Year	Thousand MT U_3O_8
1960	16.0
1961	15.7
1962	15.4
1963	12.9
1964	10.7
1965	9.5
1966	9.6
1967	10.2
1968	11.2
1969	10.5
1970	11.7
1971	11.1
1972	11.7
1973	12.0
1974	10.5
1975	10.5
1976	11.6
1977	13.6
1978	16.8
1979	17.0
1980	19.8
1981	17.5
1982	12.2

[a] Includes U_3O_8 production obtained by mine water, heap leaching, solution mining, or as a byproduct of another activity. Production estimates from 1960 trough 1965 are Atomic Energy Commission concentrate purchases.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1983 (converted to metric tons).

Table 2.2. Historical Annual Nuclear Plant Ordering and Cancellations[a]

Year Ordered	Total Orders Placed: Number of Units	Total Orders Placed: Net MWe	Orders Cancelled by Year of Cancellation: Number of Units	Orders Cancelled by Year of Cancellation: Net MWe
Thru 1965	20	8,960	0	0
1966	20	16,526	0	0
1967	31	26,462	0	0
1968	15	14,018	0	0
1969	7	7,203	0	0
1970	14	14,264	0	0
1971	21	20,957	0	0
1972	38	41,313	6	5,002
1973	38	43,319	0	0
1974	34	40,015	9	9,516
1975	4	4,148	10	11,729
1976	3	3,804	5	5,090
1977	4	5,040	10	10,814
1978	2	2,240	11	11,287
1979	0	0	13	15,252
1980	0	0	14	15,501
1981	0	0	6	5,781
1982	0	0	18	21,937
Totals	251	248,269	102	111,909

[a] Does not incude 8 units totaling 301.3 MWe permanently shut down.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1983.

Current issues concerning the safety of nuclear energy production, underscored by the accident at Three Mile Island, the lengthy period necessary to construct and license a reactor, the nuclear waste problem, plus slower growth in the demand for electricity generated from all types of fuels, create considerable uncertainty in projections of the demand for uranium. For several years, projections of future nuclear power-related activities have been significantly reduced.

In Appendix B we develop a set of projections for the appropriate uranium industry activities for use in this RIA. These include demand, inventory adjustments, imports, and domestic production (conventional and nonconventional). This set of projections to the year 2000 is based on a DOE Energy Information Administration forecast which approximates the uranium requirements for the mid-range case (see DOE83a for explanation of DOE mid-range case). Table 2.3 summarizes the DOE uranium demand projection.

2.1.2 Elasticity of Demand for Uranium

There are no substitutes for uranium in the production of nuclear energy. Therefore, the demand for uranium is derived directly from the demand for nuclear-powered electricity. The demand for nuclear-powered electricity depends on the demand for electricity in general and the relative costs of alternative sources of electricity.

Utilities consider the costs of producing power and the reliability of the power source when deciding what type of power plant to build. The capital costs of a nuclear reactor are large, about $2 billion (plant construction cost in constant dollars) for a typical 1,200 MWe plant. Fuel costs constitute a smaller proportion of the cost of nuclear-powered electricity, averaging around 15-20 percent (DOE82c). Once a utility has decided to build a nuclear power plant and has invested funds in construction, increases in fuel costs would not deter completion and operation of the plant. Therefore, the demand for uranium is insensitive to its price, especially in the short run. In other words, the demand for uranium is perfectly inelastic in the short run. In the long run, there may be some elasticity in the demand for uranium as the decision to build reactors may be influenced by the utilities' expectations about the cost of uranium.

2.1.3 Procurement and Pricing

Uranium is marketed and prices are quoted in the concentrate form, which is uranium oxide (U_3O_8), commonly referred to as yellowcake. There are three categories of uranium procurement: contract price, market price, and other. Contract price procurement involves agreeing on a price at the time the contract is signed, although physical delivery takes place in the future. Market price procurement bases the price of the contract on market prices at the time of delivery. Market price procurement may frequently include terms that establish a price floor, a cost floor, a ceiling price, or some combination of these. The "other" procurement type

Table 2.3. Summary of Projection of Uranium Industry Demand

Year	Industry Demand (Thousands of MT U_3O_8)
1983	12.7
1985	17.0
1990	18.1
1995	20.4
2000	26.9

Source: U.S. Department of Energy,
Energy Information Administration
(Gene Clark, July 11, 1983).

refers to arrangements that fall outside the contract or market price categories, such as captive production. Captive production relates to buyers with direct control of uranium properties and accounts for about one-half of the "other" arrangements for deliveries from 1982 through 1991, according to DOE (DOE83b). Table 2.4 presents the distribution, by year of delivery, of the types of domestic uranium procurement arranged as of January 1, 1983, for the 1982-1991 period. This table shows that about 90 percent of anticipated uranium deliveries from 1982 to 1991 will be purchased under either contract or market price contracts.

Before 1975, contract price procurement was used almost exclusively, while in the 1976-1982 period, procurement shifted significantly to market price contracts and other procurement. New procurement in 1982 was 73 percent market, 17 percent contract, and 10 percent "other."

Table 2.5 shows the average contract prices for 1982-1991 deliveries for which U.S. buyers and producers reported price data in DOE's January 1983 survey of uranium marketing activity. These prices are stated in year-of-delivery dollars and, therefore, reflect estimates of escalation in the contracts. Market price settlements for 1982 and 1983 are included with the contract prices since, as settled prices, they are similar to contract prices. The average uranium price increases from $38.37 per pound in 1982 to $58.91 per pound in 1991.

Table 2.6 presents the average floor price of market price contracts for the period 1982-1991, as reported in the DOE survey. The average floor price, stated in year-of-delivery dollars, increases from $51.27 per pound in 1982 to $76.85 per pound in 1991.

Although most yellowcake is sold through long-term contracts rather than on the spot market, the spot market is important as an indicator of prices and the general financial health of the industry. The major participants in the spot market are the producers and the utilities. From 1972 to 1979 the price of uranium rose 700 percent from roughly $6 per pound to over $40 per pound. Starting in 1979, the spot price of uranium (Nuexco Exchange Value) has experienced considerable weakness, declining from a high of $43 to a low of $17 per pound in September 1982. The price has rebounded slightly to $24 per pound as of July 1983. At these low prices, few domestic operations are profitable, even before additional pollution controls, due to general inflation and the increase in production costs due to a declining ore grade. Table 2.7 shows the average annual spot price of uranium.

During the sixties and seventies, many uranium mines and mills operated with ore that contained approximately 0.2 percent uranium. Because the richer deposits have been exhausted, the ore grade in new mines has fallen to 0.10 to 0.15 percent uranium. The effect of the lower ore grade is to increase costs because each ton of ore that is mined yields less salable product.

Table 2.4. Types of Domestic Uranium Procurement Arrangements as of January 1, 1983

Year of Delivery	Percentage of Deliveries by Procurement Type			Total Deliveries (Thousand MT U_3O_8)
	Contract Price	Market Price	Other	
1982	42	53	5	10.5
1983	29	66	5	9.4
1984	23	68	9	8.6
1985	25	65	10	9.3
1986	24	61	15	9.9
1987	22	62	16	8.8
1988	22	68	10	8.1
1989	21	68	11	7.4
1990	18	67	15	7.7
1991	20	60	20	7.6
1982-1991	25	64	11	87.3

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983.

Table 2.5. Average U.S. Contract Prices & Market Price Settlements as of January 1, 1983

Year	Reported Price Per Pound U_3O_8 (Year of Delivery Dollars)	Percent of Commitments with Reported Prices	Quantity of Uranium with Reported Prices (Thousand MT U_3O_8)
1982	38.37(a)	87	7.6
1983	35.62(a)	90	3.4
1984	44.84	89	1.5
1985	50.00	81	1.6
1986	48.98	77	1.4
1987	52.20	71	1.0
1988	46.65	57	0.8
1989	49.59	65	0.8
1990	57.16	59	0.6
1991	58.91	64	0.7

(a)Includes settlements of market price contracts. The 1982 and 1983 data do not include uranium delivered or to be delivered under litigation settlements.

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983.

Table 2.6. Average Floor Prices of U.S. Market Price Contracts as of January 1, 1983 (Year-of-Delivery Dollars)

Year	Reported Price Per Pound U_3O_8	Percent of Commitments with Reported Floor Prices	Quantity of Uranium with Reported Prices (Thousand MT U_3O_8)
1982	51.27	74	2.4
1983	53.49	93	2.5
1984	55.93	94	2.6
1985	61.05	92	2.4
1986	62.84	91	2.4
1987	65.50	90	2.1
1988	70.74	100	2.0
1989	75.05	100	1.8
1990	72.39	100	2.2
1991	76.85	100	2.2

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983.

Table 2.7. Average Annual Spot Price for Uranium (current dollars)

Year	Spot Price[(a)] (\$ per lb. U_3O_8)
1970	6.24
1971	6.48
1972	5.95
1973	6.41
1974	11.45
1975	23.68
1976	39.70
1977	42.20
1978	43.23
1979	42.57
1980	32.93
1981	25.00
1982	20.16

(a) NUEXCO average annual price.

Source: American Metal Market,
Metal Statistics,
for selected years.

2.2 Supply

Major sources of supply of uranium for domestic consumption are domestic mining and milling operations, domestic inventories, and imports of foreign uranium. Besides conventional uranium mills, domestic yellowcake is produced from solution mining, mine water, heap leaching, or as a byproduct of another activity (such as phosphoric acid production). Historically, about 90 percent or more of yellowcake has been produced by conventional mills. However, the conventional mill share has decreased considerably in the last few years. In 1980, the conventional share was 85 percent (DOE81a), in 1981 it was 81 percent (DOE82a), and in 1982 it was 75 percent (DOE83d).

The sharp increases in the price of uranium that occurred in the mid-1970's stimulated new mining activity. Milling capacity also increased in the last decade, nearly doubling from about 24,000 MT ore/day in 1975 to a level of about 46,000 MT ore/day in January 1981. Table 2.8 shows the capacity of conventional mills and the capacity utilization rate for the years 1975 through 1982. The increased mining and milling activity coupled with reduced demand projections for nuclear power created a surplus of uranium in 1980 forcing several mills to go on standby. During 1981 and 1982, ten mills, accounting for capacity of about 19,000 MT ore/day, ceased operations, while the average capacity utilization rate for the industry as of September 1982 was only 69 percent. Some mills are operating at as little as 20 percent capacity (deV82).

Based on projections of the demand for electricity and the expected expansion of nuclear power, utilities began making commitments to purchase large amounts of uranium in the mid-1970's. By 1980, utility inventories were at record high levels, the demand for electricity in general was lower than the expected level, and concern was widespread over the accident that shut down the Three Mile Island No. 2 reactor. During the time leading up to and following these events, a number of nuclear reactor orders were cancelled. An indication of the high level of inventories is that utilities sold a portion of their uranium inventories on the spot market in early 1980 when uranium prices were higher (CRB80). Table 2.9 shows inventory levels on January 1 for 1981, 1982, and 1983. Total inventories held by all buyers increased by 6 percent from January 1982 to January 1983, compared to a 15 percent increase from January 1981 to January 1982. Most of last year's increase is due to increases in inventories of natural uranium and UF_6 as inventories of enriched UF_6 and fabricated fuel decreased over the past year. Inventory to meet one year of the utilities' needs is considered to be adequate (Co79). As of January 1983, utilities were holding 62,100 metric tons of uranium. This figure is about four times greater than the estimated 1982 consumption by utilities of 15,000 metric tons (as measured by deliveries to DOE enrichment plants - see Table 2.12), and about five times greater than 1982 total domestic uranium production of 12,200 metric tons.

Table 2.8. Conventional Uranium Mill Nominal Capacity and Utilization Rates

Year	Nominal Capacity, as of January 1 of each year (Metric Tons Ore/Day)	Capacity Utilization Rate (Percent)
1975	24,180	83
1976	25,810	87
1977	28,270	75
1978	35,520	91
1979	39,740	90
1980	44,500	NA
1981	46,300	NA
1982 (Jan.)	45,200	NA
1982 (Sep.)	31,100	69
1983	30,600	NA

NA = Not available.

Sources: Nominal capacity as of January 1 for each year is from U.S. Department of Energy, Statistical Data of the Uranium Industry, selected years.

Capacity utilization rates for 1975-1979 is from U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, September 1980.

Capacity and utilization rate for September 1982 is from Paul C. deVergie, et al., "Production Capability of the U.S. Uranium Industry," presented at Nuclear Assurance Corporation Uranium Colloquium V, Grand Junction, Colorado, October 6-7, 1982.

Table 2.9. Uranium Inventories Held by Buyers
(Metric Tons U_3O_8 Equivalent)

	All Buyers As Of			Utilities As Of		
	1/1/81	1/1/82	1/1/83	1/1/81	1/1/82	1/1/83
Natural Uranium(a)	36,000	41,400	47,800	29,600	34,900	40,600
(Foreign-Origin)	(4,500)	(4,400)	(7,600)	(3,100)	(3,600)	(5,700)
Enriched Uranium(b)	16,600	19,400	17,500	15,100	18,000	17,200
(Foreign-Origin)	(600)	(700)	(1,500)	(500)	(700)	(1,500)
Natural UF_6 under Usage Agreements	4,900	5,100	4,400	4,600	5,100	4,400
(Foreign-Origin)	(50)	(200)	(200)	(50)	(200)	(200)
Total Uranium	57,500	65,800	69,700	49,300	58,000	62,100
(Foreign-Origin)	(5,200)	(5,600)	(9,300)	(3,700)	(4,500)	(7,400)

(a) Includes natural UF_6, but does not include natural UF_6 inventories at DOE enrichment plants for 1981 and 1982.

(b) Includes fabricated fuel.

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983 (converted to metric tons).

Note: Numbers may not add to totals due to independent rounding.

An additional source of supply of uranium for the United States comes from imports. Imports of foreign uranium constitute approximately 18 percent of total U.S. consumption, and this percentage is expected to grow. Section 2.2.2 discusses imports and exports of uranium in detail.

2.2.1 Uranium Mill Location, Ownership, and Operating Status

The focus of this RIA is the conventional uranium milling segment of the industry. As of January 1983, there were 27 licensed conventional uranium mills of which only 14 were operating, while ten were on standby. The conventional mills are located in the western States of Colorado, New Mexico, Washington, Wyoming, Utah, South Dakota, and Texas. In addition to the 24 mills that were either operating or on standby, there were two other licensed mills (Edgemont, South Dakota, and Ray Point, Texas) which had tailings piles but had not operated for many years. One other licensed mill (Bokum Resources at Marquez, New Mexico) had been constructed but never operated and had no plans to operate in the future due to financial and legal complications. The quantity of tailings existing at the 26 sites with tailings piles as of the beginning of 1983 was about 175 million metric tons. Table 2.10 gives the location, ownership, capacity, tons and acreage of mill tailings, and operating status for each of the 27 conventional mills. The estimates of tons and acreage of tailings accumulated at each mill site were obtained from several sources. These included the U.S. Nuclear Regulatory Commission, the New Mexico Department of Health and Environment, the Colorado Department of Health, the Texas Department of Health, the Washington Department of Social and Health Services, the South Dakota Department of Water and Natural Resources, and the U.S. Department of Energy Commingled Uranium Tailings Study (DOE82b).

Horizontal integration occurs when a company produces more than one type of product, or when a company purchases or merges with a competitor. In the late 1940's there were many purchases and mergers of small uranium mining firms which resulted in the formation of the United Nuclear Corporation. A subsequent joint venture between United Nuclear and Homestake Mining Company established a substantial operation, measured by both reserves and milling capacity (Ta79). A more recent example is Union Carbide buying a majority interest in the Energy Fuels Nuclear Blanding mill (NU83).

There are currently 23 companies that own conventional uranium milling operations. Major oil and mining companies are prominent in the industry. Kerr-McGee, Atlantic Richfield (Anaconda), Exxon, Getty Oil (Petrotomics), Phelps Dodge (Western Nuclear), and Newmont (Dawn) mill uranium. Other large producers include Union Carbide, UNC Resources (formerly United Nuclear), and Pathfinder Mines (an independent subsidiary of General Electric). Many of the companies that are prominent in the uranium industry are also prominent in mining other metals.

Table 2.10. Status of Licensed Conventional Mill Sites in the United States as of January 1, 1983

State	Location	Name and/or Owner	Year Mill Started	Max. Licensed Mill Capacity (MT Ore/Day)	MT of Tailings (Millions)	Size of Tailings Pile (Acres)	Operating Status
Colorado	Canon City	Cotter Corp.	1958	1,100	1.7	165	Active
	Uravan	Union Carbide Corp.	1950(a)	1,200	9.0	85	Standby
New Mexico	Seboyeta	Sohio-Reserve	1976	1,500	1.9	140	Standby
	Church Rock	United Nuclear Corp.	1977	2,700	3.2	200	Standby
	Bluewater	Anaconda	1953	5,400	20.7	300	Standby
	Ambrosia Lake	Kerr-McGee Nuclear Corp.	1958	6,300	27.6	328	Active
	Milan	Homestake Mining Co.	1958	3,100	19.2	210	Active
	Marquez	Bokum Resources Corp.	-	2,000	-	-	Closed
South Dakota	Edgemont	Tennessee Valley Authority	1956	500	2.1	123	Closed
Texas	Panna Maria	Chevron	1979	2,300	3.3	160	Active
	Falls City	Conoco and Pioneer-Nuclear Inc.	1972	3,100	8.0	240	Standby
	Ray Point	Exxon, USA (Susquehanna-Western)	1970	800	0.4	47	Closed
Utah	Blanding	Energy Fuels Nuclear	1980	1,800	1.1	116	Active
	La Sal	Rio Algom Corp.	1972	700	2.3	100	Active
	Moab	Atlas Corp.	1956	1,300	9.3	128	Active
	Hanksville	Plateau Resources, LTD.	1982	700	0.0	68	Standby
Washington	Ford	Dawn Mining Co.	1957	400	2.9	133	Standby
	Wellpinit	Western Nuclear	1978	1,800	2.3	89	Standby
Wyoming	Gas Hills	Federal-American Partners	1959	900	5.4	117	Standby
	Gas Hills	Pathfinder Mines Corp.	1958	2,300	8.6	248	Active
	Powder River (Bear Creek)	Rocky Mountain Energy/Mono Power	1977	1,800	4.5	120	Active
	Powder River (Highland)	Exxon, USA	1972	2,900	6.5	200	Active
	Jeffrey City	Western Nuclear Corp.	1957	1,500	7.0	167	Standby
	Gas Hills	Union Carbide Corp.	1960	1,300	6.5	146	Active
	Shirley Basin	Pathfinder Mines Corp.	1971	1,600	5.3	400	Active
	Shirley Basin	Petrotomics Co.	1962	1,400	5.0	140	Active
	Red Desert	Minerals Exploration Co.	1981	2,700	10.9	174	Active
			TOTALS	30,600(b)	174.7	4,344	

[a] Ore processed at the Vanadium facility for the Manhattan project in 1943.

[b] Total capacity of 14 mills in active operating status as of January 1, 1983. Additional capacity of 19,200 MT ore/day from 10 mills was on standby as of this date.

Concentration ratios for the uranium milling industry are shown in Table 2.11 for selected years from 1971 to 1982. The peak concentration, as measured by the eight-firm ratio, occurred in 1975 as this ratio reached 88 percent. As of January 1982, the eight leading milling companies accounted for 67 percent of the industry capacity.

Vertical integration can occur in the uranium industry if a company engaged in other activities required for the generation of nuclear power merges with a uranium mining firm. For example, General Electric (GE), the second largest vendor of nuclear reactors, acquired uranium holdings when it merged with Utah International in 1975. The Department of Justice required GE to spin off its uranium holdings into an independent subsidiary, the Lucky McCorporation, which changed its name to Pathfinder Mines Corporation in 1978. GE recently sold 80 percent of its interest in the Pathfinder uranium mills to the French company, Cogema (Wh83). In addition to vertical integration between nuclear reactor manufacturers and uranium mining firms, there is also considerable vertical integration between utilities and mining firms. For example, utilities such as Commonwealth Edison, Consumers Power Company, Niagara Mohawk, and Southern California Edison own or exercise substantial control over uranium mining firms. As noted in Appendix A, approximately 70 percent of uranium is milled as part of an integrated mining and milling operation. At the mills, approximately 10 to 15 percent of production is "captive" production of the owners of later stages of production.

2.2.2 Imports and Exports

A significant factor that determines import levels, and thus affects the supply of uranium for domestic uses, is United States Government policy. The Department of Energy is the only domestic processor allowed to enrich yellowcake (U_3O_8) with the isotope Uranium 235 for nuclear applications. Imports of uranium to be enriched for U.S. usage were banned from 1964 to 1976. Foreign uranium was allowed to be enriched in the U.S. and returned to the country of origin during this period. This ban, which was effectively a subsidy to the domestic uranium industry, was partially lifted in 1977 when 10 percent of each U.S. utility's enriched uranium was allowed to be of foreign origin. An additional 10 percent allowance is added each year until 1984, when the current restriction on enrichment of imported uranium is due to expire. However, due to the depressed condition of the uranium industry, Congress is considering reducing, or continuing to limit, imports of uranium for commercial uses. Therefore, this potential Congressional action introduces an additional element of uncertainty into the uranium market.

The actual use of foreign uranium in the U.S. can be measured by the amount enriched at the DOE processing plants. Table 2.12 shows the receipts of uranium at DOE plants classified by origin. In 1982, imports nearly tripled from the previous year's amount. Commitments for future

Table 2.11. Concentration in the Uranium Industry by Milling Capacity (Percent)

	1971	1975	1977	1980	1982
2 Firms	35	39	34	27	26
4 Firms	54	62	54	45	42
8 Firms	78	88	83	71	67

Sources: For the years 1971, 1975, and 1977, June Taylor and Michael Yokell, Yellowcake, The International Uranium Cartel, 1979. The years 1980 and 1982 were estimated from data in U.S. Department of Energy, Statistical Data of the Uranium Industry, GJO-100(80), 1981, and GJO-100(82), 1982.

Table 2.12. Deliveries of Uranium to DOE Enrichment Plants by Domestic Customers

Year	Origin (Metric Tons of U_3O_8)			Percent Foreign	
	U.S.	Foreign	Total	Actual	Allowable
1977	12,900	600	13,500	4.7	10
1978	10,800	700	11,500	5.9	15
1979	14,000	1,400	15,400	9.4	20
1980	10,100	1,100	11,200	9.7	30
1981	9,100	1,000	10,100	10.3	40
1982	12,300	2,700	15,000	18.1	60

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983 (converted to metric tons).

uranium deliveries by foreign sources also increased substantially in 1982. However, the data show that U.S. utilities as a whole are purchasing substantially less foreign uranium for enrichment than the percentage allowed by U.S. policy. In 1981, when the allowable foreign origin limit of an individual utility's deliveries to enrichment was 40 percent, only 10.3 percent of all utilities' deliveries were of foreign origin. In 1982, when the allowable limit was 60 percent, 18.1 percent of all utilities' deliveries were of foreign origin.

The United States also exports uranium to other countries. Table 2.13 gives historical data on U.S. imports and exports. Until 1975, the U.S. was a net exporter of uranium, with exports averaging 6 percent of domestic production. From 1975 through 1977, U.S. imports were greater than exports. Net imports represented 5 percent of domestic production during this period. In 1978, the U.S. became a net exporter of uranium again and remained so through 1980. Net exports averaged about 6 percent of production from 1978 through 1980. In 1981 and 1982, the United States once again became a net importer of uranium. Net imports in 1982 were about half the amount of domestic production. Currently, France and Taiwan are among the countries purchasing U.S. uranium. However, both Canada and Australia contain substantial reserves of low cost deposits of uranium, and South Africa is increasing its production capacity. In South Africa, uranium is produced at low cost because it is a byproduct of gold mining. United States production costs are higher due to lower ore grades, strict mine safety requirements, and smaller sized mines (DOE81b).

Predicting the degree of reliance on imported uranium for future domestic use is very uncertain. Putting the potential import restrictions aside, the use of foreign uranium, though economic, appears to be limited for other reasons. With a significant reliance on imports, U.S. utilities, and the nation as a whole, may be vulnerable to a Mid-East oil-type embargo which could result in substantial price increases and curtailments of supplies. Since nuclear reactors are designed for thirty to forty years of operation, utilities need a uranium supply for a long time frame. There is evidence that U.S. utilities would be willing to pay a premium for U.S. supplied uranium in order to get a reliable supply of fuel over a long time period (Re81, Wh83). Utility spokesmen, both in favor and against import restrictions, have often stated that it is essential to have a stable domestic uranium production industry capable of meeting electric utilities' needs when called upon (Hu82, Ma82). The "Buy American" philosophy seems to be a real phenomenon in the uranium business. It is felt that U.S. mills will set prices due to U.S. buyer preference for domestic uranium (Ha82). On the other hand, though, pressure from Public Utility Commissions to minimize costs will force utilities to purchase uranium that is the most economic. Consequently, we cannot accurately forecast the role of imports in supplying future uranium requirements.

Table 2.13. U.S. Imports and Exports of Uranium (U_3O_8) for Commercial Uses

Year	Imports (Metric Tons)	Exports (Metric Tons)
1966	0	363
1967	0	635
1968	0	726
1969	0	454
1970	0	1,905
1971	0	181
1972	0	91
1973	0	544
1974	0	1,360
1975	600	500
1976	1,600	500
1977	2,500	1,800
1978	2,400	3,000
1979	1,400	2,800
1980	1,600	2,600
1981	3,000	2,000
1982	7,800	2,000

Source: U.S. Department of Energy, Energy Information Administration, 1982 Survey of United States Uranium Marketing Activity (Pre-Publication Release), July 21, 1983 (converted to metric tons).

2.2.3 Uranium Reserves

The United States has the largest known uranium deposits in the world. Thus, the potential U.S. supply of uranium is more than adequate to meet demand. Of the total "reasonably assured" world resources at $30 per pound, the United States has 20 percent, Australia - 17 percent, South Africa - 14 percent, and Canada - 13 percent (DOE83c). At $50 per pound reasonably assured resources, this distribution is United States - 24 percent, South Africa - 14 percent, Australia - 13 percent, and Canada - 10 percent. "Reasonably assured resources" refers to uranium that occurs in known deposits that could be recovered with currently proven technology and corresponds to DOE's "Reserves" category (DOE83c). Table 2.14 shows historical estimates of uranium reserves in the United States. The reserves are listed by "forward cost" categories, e.g., $15/lb. Forward costs include operating and capital costs, in current dollars, that must be incurred to produce the uranium (DOE80). Not included in forward costs are all previous exploration and development expenses, and future income taxes, profits, and the cost of money. It is common practice in the uranium industry to multiply the forward costs by 1.7 to obtain full costs (Se80).

2.2.4 Employment

Overall employment in the uranium industry is shown on Table 2.15, for the years 1973 through 1982. The growth in employment in the industry is indicative of the prosperity the industry was enjoying during this period. From 1973 to 1979 total employment increased more than three-fold.

Detailed employment data for the conventional uranium mining and milling segments of the industry are shown separately in Table 2.15a for the year 1982. Total employment totaled 7,013 people for the two segments in 1982, down 56 percent from a total of 15,991 in 1979. With additional mills going on standby in 1983, employment has decreased even further.

2.3 Financial Condition

The uranium industry is currently in a period of contraction. The spot price of uranium averaged only $25 per pound in 1981 and $20 per pound in 1982, while production costs in the U.S. average about $30 per pound (BW81, PD83). Since many domestic operations are unprofitable when uranium is selling at so low a price, many have closed or delayed mining and milling projects. The outlook for a rise in prices in unclear. Uranium prices will rise when more nuclear reactors are built and licensed, and analysts are unsure when the nuclear power industry will begin to expand.

Financial data for six companies in the uranium industry are shown in Tables 2.16 and 2.17, covering the period 1976 through 1982. As a group, these six companies provide a reasonable financial representation of the

Table 2.14. Historical Estimates of Uranium Reserves

As of Jan. 1	Thousand MT U_3O_8 $15/lb	$30/lb	$50/lb	$100/lb
1970	288			
1971	355			
1972	472			
1973	472			
1974	472	575		
1975	380	544		
1976	390	581		
1977	372	617	762	
1978	336	626	807	
1979	263	626	835	
1980	204	585	849	1,018
1981	102	426	714	938
1982	0	186	539	811
1983	0	163	522	806

Note: Reserves reported at $30, $50, and $100/lb include reserves in all lower cost categories. This table does not include byproduct uranium.

Source: Statistical Data of the Uranium Industry, U.S. Department of Energy, January 1, 1983 (converted to metric tons).

Table 2.15. Employment in the Uranium Industry(a)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Exploration	1,557	1,697	2,049	2,793	4,140	4,449	4,066	3,370	NA	NA
Mining(b)	3,516	3,928	5,386	7,603	11,453	13,338	14,219	11,768	9,009	6,242
Milling	1,522	1,668	2,237	2,727	3,175	3,615	3,476	3,251	2,367	1,956
Total	6,595	7,293	9,672	13,123	18,768	21,402	21,761	18,389	NA	NA

NA = Not available.

(a) Covers both conventional and nonconventional sources of uranium.

(b) Includes employees working in recovery of uranium from byproducts and solution mining.

Source: For the years 1973 to 1979, U.S. Department of Energy, Office of Uranium Resources and Enrichment, "The Domestic Uranium Industry and Imports of Uranium," February 23, 1981. The estimates for 1980, 1981, and 1982 are from U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1981, January 1, 1982, and January 1, 1983, editions.

Table 2.15a. Employment in the Uranium Mining and Milling Industries (1982)[(a)]

	Underground		Open Pit							
	Miners	Serv. & Support	Miners	Serv. & Support	Operations	Maintenance	Technical	Other	Supervisory	Total
Mining										
Colorado and Utah	464	210	35	40	NA	NA	104	61	107	1,021
New Mexico	744	611	0	0	NA	NA	227	158	289	2,029
Wyoming	67	54	547	425	NA	NA	134	172	156	1,555
Other States	0	0	210	108	NA	NA	38	35	61	452
Total	1,275	875	792	573			503	426	613	5,057
Milling										
Colorado and Utah	NA	NA	NA	NA	244	193	81	66	103	687
New Mexico	NA	NA	NA	NA	236	148	66	35	99	584
Wyoming	NA	NA	NA	NA	168	129	53	34	56	440
Other States	NA	NA	NA	NA	93	68	19	31	34	245
Total					741	538	219	166	292	1,956

NA = Not Applicable.

(a)Not included are 1,185 employees working in recovery of uranium from byproducts and solution mining.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1983.

Table 2.16. Financial Information for Selected Companies in the Uranium Industry
($ in Thousands)

	Year	Atlas	Conoco	Homestake	Kerr-McGee	Pioneer	UNC
Revenues	1976	15,611	NA	22,441	96,800	NA	29,339
	1977	28,152	NA	59,141	123,300	NA	80,816
	1978	26,845	16,488	44,928	115,200	13,810	133,193
	1979	38,253	16,384	42,388	163,400	20,267	181,626
	1980	60,148	34,586	45,363	238,900	7,829	167,811
	1981	NA	NA	59,983	201,500	7,224	102,102
	1982	NA	NA	63,702	153,100	419	84,038
Operating Profit	1976	4,607	NA	10,389	32,700	NA	7,103
	1977	8,027	NA	24,622	22,300	NA	28,539
	1978	(1,925)	(20,815)	20,454	20,100	1,257	42,320
	1979	(2,159)	(21,530)	14,097	(200)	(1,004)	61,339
	1980	6,142	(30,719)	(601)[a]	30,000	(1,082)	12,243
	1981	NA	NA	5,703	26,300	(7,855)	20,537
	1982	NA	NA	15,592	20,000	(63,871)	2,409
Assets	1976	NA	NA	14,144	215,300	NA	87,222
	1977	NA	NA	45,023	236,500	NA	145,376
	1978	56,375	52,491	42,990	272,000	51,119	203,041
	1979	79,428	61,218	47,790	288,400	70,583	279,436
	1980	72,834	62,867	54,798	304,800	84,046	239,888
	1981	NA	NA	83,135	304,500	85,859	210,471
	1982	NA	NA	80,831	312,400	35,621	209,791
Depreciation Depletion	1976	NA	NA	192	7,500	NA	1,070
	1977	NA	NA	80	9,300	NA	1,952
	1978	3,331	2,876	0	13,800	8,679	5,414
	1979	4,058	3,209	17	15,600	11,253	9,677
	1980	6,212	3,957	6,980	21,300	8,718	11,952
	1981	NA	NA	5,339	16,600	5,337	6,993
	1982	NA	NA	19,953	16,300	2,096	3,249
Capital Expend.	1976	NA	NA	2,036	NA	NA	27,856
	1977	NA	NA	2,628	NA	NA	54,499
	1978	14,579	7,213	7,961	34,277	19,467	49,518
	1979	21,870	6,937	8,533	28,600	23,513	39,156
	1980	7,453	7,999	12,521	17,900	17,567	46,662
	1981	NA	NA	12,036	14,200	9,238	14,386
	1982	NA	NA	1,025	7,300	3,123	8,606

NA = Not Available.

(a) Includes an $8,075 loss on settlement of uranium litigation, would otherwise have been (8,075) - 601 = +$7,474.

Source: Corporate annual reports, Securities and Exchange Commission (SEC) 10-K reports.

Table 2.17. Financial Ratios for Selected Companies in the Uranium Industry (Percentage)

	Year	Atlas	Conoco	Homestake	Kerr-McGee	Pioneer	UNC
Operating Profit/ Revenue	1976	29.5	NA	46.3	33.8	NA	24.2
	1977	28.5	NA	41.6	18.1	NA	35.3
	1978	-	-	45.5	17.4	9.1	31.8
	1979	-	-	33.3	-	-	33.6
	1980	10.2	-	16.5(a)	12.6	-	7.3
	1981	NA	NA	9.5	13.1	-	20.1
	1982	NA	NA	24.5	13.1	-	2.9
Operating Profit/ Assets	1976	NA	NA	73.4	15.2	NA	8.1
	1977	NA	NA	54.7	9.4	NA	19.6
	1978	-	-	47.6	7.4	2.5	20.8
	1979	-	-	29.5	-	-	22.0
	1980	8.4	-	13.6(b)	9.8	-	5.1
	1981	NA	NA	6.9	8.6	-	9.8
	1982	NA	NA	19.3	6.4	-	1.1
Depreciation Depletion/ Revenues	1976	NA	NA	1.8	7.7	NA	3.6
	1977	NA	NA	.3	7.5	NA	2.4
	1978	12.4	17.4	-	12.0	62.8	4.1
	1979	10.6	19.6	.04	9.5	55.5	5.3
	1980	10.3	11.4	15.4	8.9	111.0	7.1
	1981	NA	NA	8.9	8.2	73.9	6.8
	1982	NA	NA	31.3	10.6	500.2	3.9
Capital Expenditure/ Revenue	1976	NA	NA	9.1	NA	NA	95.0
	1977	NA	NA	4.4	NA	NA	67.4
	1978	54.3	43.7	17.7	29.8	141.0	37.2
	1979	57.2	42.3	20.1	17.6	116.0	21.6
	1980	12.4	23.1	27.6	7.5	224.0	27.8
	1981	NA	NA	20.1	7.0	127.9	14.1
	1982	NA	NA	1.6	4.8	745.3	10.2

NA = Not Available.

- = Loss Year.

(a)16.5 percent without litigation.

(b)13.6 percent without litigation.

Source: Corporate annual reports, Securities and Exchange Commission (SEC) 10-K reports.

uranium industry. Tables 2.16 and 2.17 show considerable variations in the data both within companies and between companies. In general, the tables indicate the declining financial health of the industry. The financial information has been assembled from corporate annual reports and Securities and Exchange Commission (SEC) 10-K reports. Many companies in the uranium industry have more than one business segment. The information in the tables is from the business segment that includes uranium, although other products may also be included, such as other metals. Therefore, the data should be compared over several years and among several companies to develop a profile of a typical uranium company.

Capital investment expenditures for the domestic uranium mining and milling segments are shown in Table 2.18. Total capital expenditures rose at an average annual rate of 29 percent from 1975 to 1980. Expenditures for 1982 totaled $92 million, a decrease of 82 percent from the 1980 level of $515 million. Planned expenditures for 1983 and 1984, estimated to be only $36 and $32 million, respectively, reflect a continuation of the decline in capital investment.

Table 2.18. Capital Investment for Domestic Uranium Production

	1975	1976	1977	1978	1979	1980	1981	1982	1983 (Planned)	1984 (Planned)
Mine										
Companies Reporting	22	29	31	25	26	34	29	23	15	16
Expenditures ($ Millions)	124	200	325	271	282	273	212	81	26	23
Mill										
Companies Reporting	18	24	26	19	26	27	22	15	13	8
Expenditures ($ Millions)	22	55	167	156	203	242	59	11	10	9
Total Expenditures ($ Millions)	146	255	492	427	485	515	271	92	36	32

Note: Based upon surveys conducted from January 1, 1976, to January 1, 1983.

Source: U.S. Department of Energy, Statistical Data of the Uranium Industry, January 1, 1983.

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3. Objectives of Standards and Control Methods

3.1 Goals of Radiation Protection for Tailings Disposal

Standards for the protection of public health, safety and the environment must be written to address predetermined objectives or goals. We have identified five goals which describe the purpose in developing these standards. These goals are:

1. Discourage future uses of tailings, especially in or near dwellings or workplaces. The past use of tailings as construction materials has caused increases in the levels of radon decay products in buildings. People in these buildings have a much greater risk of radiation-induced lung cancer.

2. Protect the population from radon decay products emanating from tailings piles. Radon exposures to people living in the vicinity of tailings piles can be above background and thus lead to increased risk to these individuals. Also, since radon is a noble gas with a radioactive half-life of 3.8 days, any radon released from tailings can travel long distances before it decays to innocuous levels. As the radon decays, the decay products expose large numbers of people to very low levels of radiation. Since any level of radiation exposure presents some risk to humans, reduction of this risk must be considered regardless of how small the risk to any one individual.

3. Prevent the surface spread of tailings. Tailings are spread about the local area by wind and precipitation. This causes radiation exposure to the local residents from both radon decay products and external gamma radiation. Tailings can be a significant source of external gamma radiation at low concentrations in soil. For external gamma radiation, NCRP #45 (NP75) recommends using a dose conversion factor of 13.9 mrem per year per pCi of Ra-226 per gram of soil covering a large area. In addition, the spread of tailings may contaminate surface water resources. The health risk depends on the amount of dispersed tailings and varies at the different sites. At some sites it is estimated this may be a significant risk.

4. Protect groundwater sources. Contamination of groundwater occurs when water comes in contact with tailings, leaches hazardous or toxic materials from the tailings, and then moves into groundwater aquifers through fissures, percolation, or other means. This water contains nonradioactive contaminants as well as radioactive contaminants. Some evidence indicates that when a pile is no longer used and dries out, most of the contamination stops. The health risk depends on the contaminant concentrations in the water and the uses of the water (human consumption, livestock watering, irrigation, etc.).

5. Provide control of the tailings for very long times. Because of the long lifetimes of the radioactive contaminants (thorium-230, for example, has a half-life of about 75,000 years) and the presence of other toxic materials (which never decay), the potential for harming people will persist indefinitely. Many interrelated factors affect the long-term performance of tailings disposal methods. They include external phenomena, such as erosion, earthquakes, floods, windstorms, and glaciers; internal chemical and mechanical processes; and human activities. Predictions of the stability of disposed tailings become less certain as the time period increases. Beyond several thousand years, long-term geological processes and climatic change will determine the effectiveness of most "permanent" control methods.

To accomplish the above objectives, we have translated the first four goals of the standards into categories of regulatory controls. Protection for long periods of time, goal number five, applies to each of the other objectives and is discussed in Section 3.3. These controls are listed in four general classes:

I. discourage misuse;

II. radon control;

III. prevention of the spread of radioactive materials by wind and surface water;

IV. prevention of groundwater contamination.

It should be understood that some of these classes are interrelated. For instance, radon control can be achieved by placing a thick earth cover over the tailings. This method also provides significant control for groundwater protection and prevention of misuse. Despite the fact that these classes of control are not mutually exclusive, this classification appears to offer a reasonable approach for analyzing control methods and developing regulatory options.

These four classes and the likely methods of providing such controls are discussed in the following sections. More detailed discussions of these control methods are presented in the FEIS.

3.2 Control Methods

3.2.1 Discourage Misuse

Materials contaminated with radium-226 and thorium-230 must be isolated so that they are not readily available for use in the construction of dwellings and other occupiable buildings. Tailings are a high grade sand and can be ideal for use in construction or as fill, if the material were not a health hazard. There is real potential for harm if, as happened in Grand Junction, Colorado, people identify a disposal site as a resource area for sand. (The reader should refer to the FEIS for more information on the Grand Junction experience.)

Various methods can be used for isolating the tailings ranging from a simple earthen cover to a deep mine. Greater amounts of material, such as earth, placed between the tailings and the environment increase the isolation of the tailings. When considered in this way, greater, or better, isolation means there is a smaller likelihood that man will intrude into the disposed tailings.

The readily available method of tailings disposal is covering the tailings with earth. Other methods are possible but are also more costly. Therefore, this analysis limits the consideration of isolation methods to those involving earthen covers. However, it is recognized that some day other methods providing better isolation may become economically competitive.

The amount or thickness of soil needed to provide isolation is not amenable to direct scientific calculation. Perhaps the best approach is to review the depths to which excavations for common activities are made. Excavations are routinely made to six to eight feet for public utilities (water and sewer pipes, power lines, telephone lines). Footings for house foundations are often placed at an eight foot depth. In colder climates it is important that water lines and foundations be placed below the frost depth to avoid freezing problems. Graves are also dug to a depth of six feet, or more.

3.2.2 Radon Control

Methods for the prevention of radon release into the atmosphere range from simple barriers, such as earth or plastic sheeting, to higher technology means, such as incorporation of the tailings in asphalt or concrete or chemical processing to remove the radon precursors. Radon control methods considered in this analysis are limited to earth covers. Plastic and asphalt covers are not considered since they degrade rapidly in most cases when exposed to the sun. The more advanced methods are not considered since costs are high and not well established, and their effectiveness for radon control is questionable.

Earth placed over tailings slows the movement of radon into the atmosphere by various attenuation processes. When the earth is moist, attenuation increases. Different soils have different attenuation properties; these can be approximately quantified in terms of a quantity called the "half-value layer" (HVL). The HVL is that thickness of cover material (soil) that reduces radon emission to one-half its value.

Figure 3.1 shows the percentage of radon that would be predicted to penetrate various thicknesses of materials with different HVL's. These values are nominal; the actual HVL may vary significantly. From Figure 3.1 it can be seen that 3 meters of sandy soil (HVL = 1.0 meters) are projected to reduce the radon released from tailings by about 90 percent. Soils with better attenuation properties would require less thickness to achieve the same reduction. For example, 1 meter of compacted moist soil (HVL = 0.3 meters) would be predicted to reduce the radon release by about 90 percent.

A more complete treatment of radon attenuation based on the work of Rogers (Ro81) is given in Appendix P of the NRC Generic EIS for mill tailings. That analysis concludes that the effectiveness of an earthen cover as a barrier to radon depends most strongly on its moisture content. Typical clay soils in the uranium milling regions of western United States exhibit ambient moisture contents of 9 percent to 12 percent. For nonclay soils, ambient moisture contents range from 6 percent to 10 percent. Table 3.1 provides, as an example, the cover thicknesses needed to reduce the radon emission to 20 pCi/m^2s for the above ranges of soil moisture. Four examples of tailings are shown that cover the probable extreme values of radon emissions from bare tailings at existing sites (100 to 1000 pCi/m^2s); the most common values lie between 300 pCi/m^2s and 500 pCi/m^2s.

In practice, design techniques must take account of uncertainties in the measured values of the specific materials used, the tailings to be covered, and predicted long term values of equilibrium moisture content for the specific location, in order to assure meeting any given radon emission limit over the long-term. The uncertainty in predicting reductions in radon flux increases rapidly as the required radon emission limit approaches background. Even at 20 pCi/m^2s the uncertainty may approach a factor of three (Ro83).

3.2.3 Prevention of Spread of Tailings and Control of External Radiation

Methods for control of wind blown and precipitation-carried tailings include earthen and plastic coverings, chemical and asphalt binders which are sprayed on the tailings, grading and contouring to eliminate steep slopes, revegetation, and others. Chemical and asphalt sprays do not last long on tailings and are more suitable for use during the operating time of a mill. For this analysis a combination of grading and contouring slopes, covering with 0.5 meter of earth, landscaping, and continuing maintenance is considered the minimum control for wind blown and precipitation carried tailings.

Methods that provide protection from external gamma radiation require that mass be placed over the source of the penetrating (gamma) radiation. Thus, a plastic sheet has no effect on gamma levels whereas a layer of earth is quite effective in reducing gamma levels.

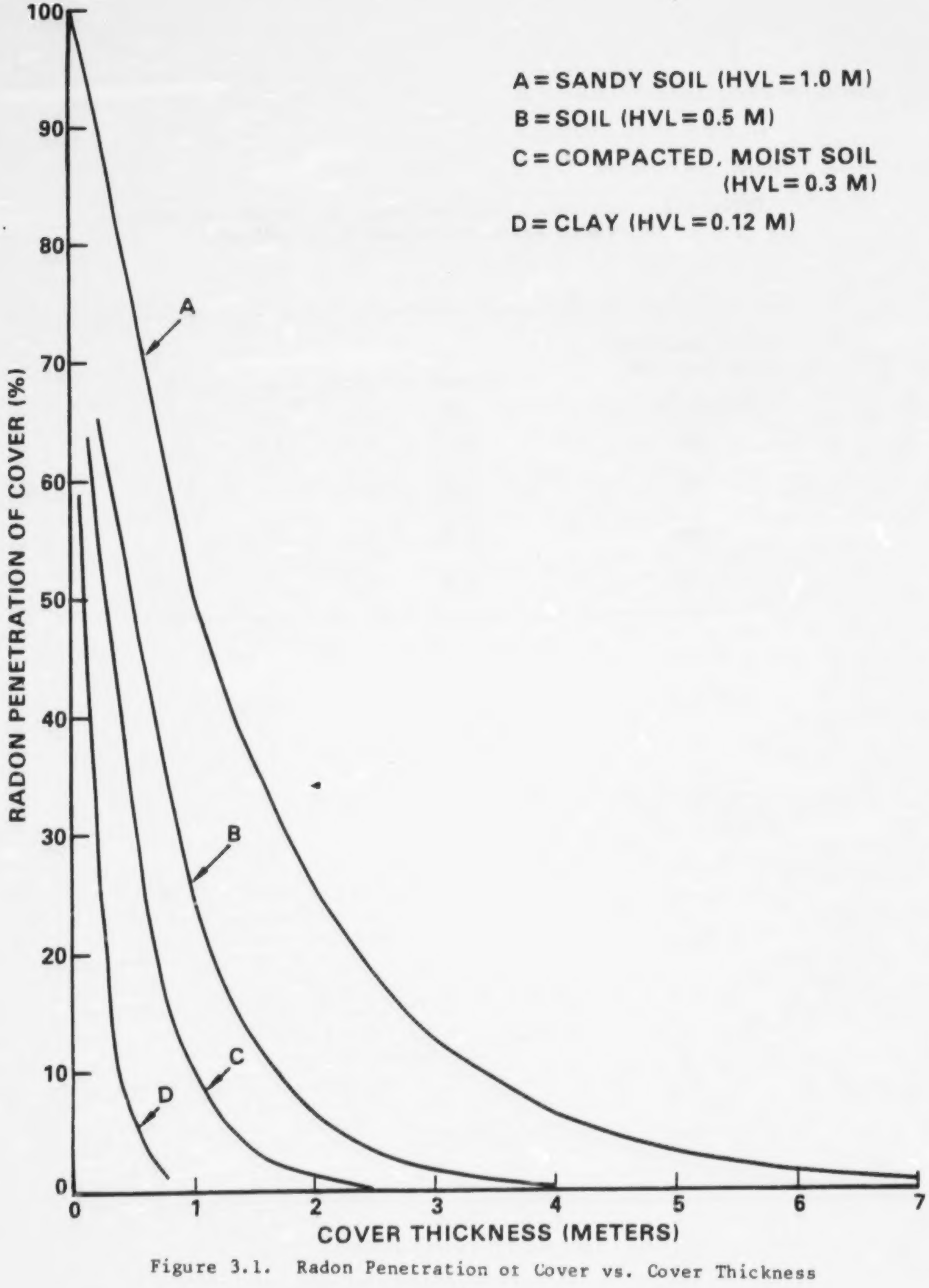

Figure 3.1. Radon Penetration of Cover vs. Cover Thickness

Table 3.1. Estimated Earthen Cover Thickness (in meters) to Reduce Radon Emissions to 20 pCi/m^2s

Radon Emission from Tailings (pCi/m^2s)	Percent Moisture Content of Cover			
	6	8	10	12
100	1.7	1.3	1.0	0.7
300	2.8	2.1	1.5	1.1
500	3.4	2.6	2.0	1.5
1000	4.1	3.2	2.4	1.8

The amount or thickness of earth that will attenuate the gamma radiation to one-half its initial value is also called a half-value-layer (HVL). As with radon adsorption, the HVL for gamma attenuation depends on soil composition, compaction, moisture content, and other factors. The average HVL of compacted soil is about 0.1 meter. Therefore, a soil thickness of 0.5 meter will reduce the gamma to about 3% of its initial value from the uncovered tailings and 1 meter of soil would reduce it to about 0.1% of its initial value.

A typical tailings pile may have a radium-226 concentration of 300 to 500 pCi/g. This produces a gamma absorbed dose rate in air as high as 7,000 mrad/year on top of the uncovered tailings, assuming a homogeneous distribution of the radium-226 in the tailings. An earth covering of 1 meter would reduce this absorbed dose rate in air to about 7 mrad/year. This is slightly less than the total gamma dose from the uranium-238 series under average background conditions.

3.2.4 Groundwater Protection

Uranium mills produce large quantities of radioactive and toxic materials in their tailings. These tailings have been stored in unlined impoundments which in many cases were located on permeable soil. Water in the tailings leaches toxic and radioactive materials from the tailings. This leachate with dissolved toxic and radioactive materials can seep into the underlying aquifers, thereby contaminating them. Several of the dissolved materials have very small removal rates in soils and thus can travel some distance in the aquifer.

Arsenic, selenium, lead, manganese, molybdenum, and vanadium are present in varying amounts in the tailings, are highly mobile (small removal rates in soils), and have been found in groundwater above Federal and State limits at distances up to 1.5 miles from tailings piles at seven sites. There are no Federal regulations limiting concentrations in groundwater per se. In general, EPA's National Interim Primary Drinking Water Regulations (NIPDWR) are used to assess the toxicity or health risk of groundwater contamination. This is consistent with the goal established under the SWDA, as amended, regulations: to preserve the quality of groundwater for future uses. Arsenic, selenium, and lead are all assigned limits in the NIPDWR's. Manganese is assigned a limit in the secondary drinking water regulations. Molybdenum may be toxic and has been shown detrimental to cattle.

Corrective actions have already been taken at three tailings pond sites because of groundwater contamination. New, plastic-lined ponds have been constructed at the Cotter Mill, Cannon City, Colorado, and the Dawn Mill, Ford, Washington, to alleviate groundwater contamination. A groundwater cleansing system has been installed at the Homestake Mill, Grants, New Mexico. This involves two rows of wells downgradient from the tailings. Contaminated groundwater is pumped from the first row of wells and recycled; fresh water is injected into the second row of wells. More information on groundwater contamination at existing mills is contained in the FEIS.

Methods for preventing contamination of groundwater fall into four groups: (1) placing a barrier between the tailings and the aquifer that will either prevent the movement of water from the tailings to the aquifer or will remove the hazardous materials in the water by adsorption; (2) fixing the tailings into a solid mass that prevents the leaching of the hazardous materials from the tailings by water; (3) covering and contouring the pile to minimize precipitation infiltration into the tailings and to encourage runoff of precipitation; and (4) selecting a site with characteristics that minimize recharge of the aquifer and provides natural adsorption process. Since these are not all available for existing tailings piles, it is important to differentiate between existing tailings piles and new piles either at existing sites or new sites.

The protection afforded by an impermeable barrier such as plastic or an adsorption material such as clay is difficult to estimate, especially over long time periods. Potential groundwater contamination depends on the tailings management practices of the mills, including the amount of water discharged to the tailings pond, the amount of water recycled back to the mill, the years of operation, and other factors. The potential contamination also depends on the amounts of various contaminants in the tailings, the distance between the tailings and the saturated zone (the aquifer), and the geological and hydrological characteristics of the intervening materials.

EPA policy for groundwater protection for analogous surface impoundments is that protection is provided during the operational period of a tailings pond by an active water management program that includes a liner on the bottom and sides of the pond. After operations at a tailings pond cease, long term groundwater protection is provided by a cover that is installed over the tailings (EPA82).

For existing mills with existing tailings, groundwater under the pond may or may not be contaminated when these standards become effective. If the groundwater is not contaminated at a site, use of the pond could probably be continued with a continuing monitoring program. If the groundwater is contaminated, corrective actions will be required. In our view, corrective action in the worst case would require the construction of a new pond with a liner. The existing pond would be allowed to dry out and then covered. However, it is possible that moving the entire existing pile to a new lined pond could be required to provide adequate groundwater protection.

For new mills, and possibly for future tailings at existing mills, groundwater protection during operation is assumed to be provided by a plastic liner, which would cost about the same as a clay liner. Selection of a site could eliminate the need for a liner, however, if the soil at the site has proper permeability and adsorption characteristics. The total disposal system could also be different for these mill sites if abandoned surface mines or natural land depressions are nearby. Since the liner provides groundwater protection only during the operational period of a tailings pond and since, as explained in Chapter 1, this RIA only addresses the benefits and costs of the proposed disposal standards, we have omitted the cost of the liner in the cost-effectiveness analysis of alternative disposal methods in Chapter 4. In Chapter 5, where we estimate the industry-wide cost of compliance with the standards over a projected time period, we include the cost of a liner since that is a cost that future operations are likely to incur.

3.3 Protection for the Long Term or the Short Term

Mill tailings will be hazardous for a very long time, in the range of hundreds of thousands of years. This period is determined by the radioactive half-life of thorium-230 which is about 75,000 years. Methods providing control for such periods are beyond man's knowledge and experience. In addition, the presence of permanent contaminants in the tailings means that their potential hazards will remain forever.

The goal for long term protection is to provide all reasonable controls for as long a period as the potential hazards remain. Failure of the controls in this case means the loss of isolation from man and the environment. Various control methods are examined in this section.

Failures of long term methods can occur by natural phenomena and through human intrusion, or intervention. Natural phenomena change the landscape through complex interactions of erosion and deposition, flooding, climatic changes, earthquakes, vulcanism, and glaciation. Human intrusion can also take a large number of forms, ranging from common activities such as construction of dwellings and other buildings, to such things as drilling, mining, and dam building. Not all of these items would cause failures of tailings isolation since at some sites these items may actually increase isolation by, for example, depositing additional materials or soil on the tailings. Long term protection will vary considerably from site to site.

3.3.1 Lifetime of Institutional Control

Human institutions can prevent failures of tailings disposal sites. The problem here is that there is no general consensus on the length of time institutions remain effective or reliable. In its proposed criteria for management of radioactive waste (EPA78) which have been withdrawn (EPA81), EPA said that waste disposal plans should limit reliance on institutional controls to 100 years. The issue of how long reliance can be placed on institutional controls cannot be settled by scientific or technical means. Resolution of this issue will be by societal judgment. It is noted, however, that the tailings will remain hazardous for a much longer time than man's recorded history.

Institutional controls are considered active controls in that continuous monitoring and maintenance actions are performed. For example, if a cloud burst causes severe erosion of the disposed tailings cover, the responsible institution would take the corrective actions needed to restore the cover to its original depth. In contrast, a passive control method would provide protection by a thick earth cover that is contoured or graded to promote runoff without erosion. Public health protection in this latter case relies solely on the disposal system. This is the passive control approach. In general, the initial costs of passive controls will probably be greater than those of active controls. However, because technical or passive controls are more reliable and predictable over the long term than institutional or active controls, we conclude that passive controls are the preferred approach. Also because of the long term hazards involved, the question of how long institutional controls will remain viable becomes moot. In all likelihood, institutions established to provide control of the tailings cannot be assumed to last until the tailings hazards are gone.

Failure of institutional controls does not necessarily imply a complete breakdown of societal structure. The more likely situation would be the failure of the individual institution set up to provide control of the tailings through program reductions, reorganizations, or changes in priorities or through the loss of special funding mechanisms by incorporation into general funds, accounting procedures changes, or others. In short, in this context, catastrophies do not have to be assumed to have institutional breakdowns.

3.3.2 Human Intrusion

Human intrusion into tailings becomes a serious problem when the tailings are misused as construction material or fill at occupiable structures, as discussed in subsection 3.2.1. Intrusion can also increase erosion which leads to the eventual spread of tailings and increased risk to man.

The effectiveness of controls in preventing intrusion over long time periods is difficult to evaluate, at best. Probably the worst scenario is the identification of a tailings location as a resource area for construction material by residents of a nearby population center. This could lead to widespread use of tailings around residences, schools and other inhabited structures. Any controls which make a tailings location attractive as a resource area have a potential for promoting misuse. Examples are controls such as fences and covers consisting of small-sized rock. We conclude, therefore, that the disposal site should not be made attractive through the use of easily removed, valuable materials.

Prevention of intrusion by institutional controls can reasonably be expected to vary greatly from site to site. Socio-economic conditions of the area and attitudes of local residents are important factors. These factors will likely determine the length of time a fence remains an effective deterrent to intrusion, even if posted. Annual inspections and maintenance may help to prevent intrusion since people would recognize the site is of continuing interest. Periodic controls such as operation of a sprinkler system for sustaining vegetation may also be an efffective deterrent, for as long as it continues. In any case, active controls can only be counted as effective against intrusion for as long as they are practiced.

Prevention of intrusion for long time periods is more likely to be successful using passive methods. Thick earth covers, for example, can be expected to provide significant protection against intrusion as discussed in subsection 3.2.1. Other passive methods appearing effective against intrusion are deep mine disposal, below grade disposal, solidification in a cement or asphalt admixture, or coverings of a tailings cement mix.

3.3.3 Erosion

All surface disposal methods are subject to erosion. Erosion of stabilized tailings piles can occur as or be caused by sheet erosion, gully intrusion or erosion, wind erosion, and differential settlement. Nelson, et al. (Ne83), describe these various modes and discuss long-term mitigating measures in some detail.

Sheet erosion is caused by unconcentrated water flowing directly over the surface of the tailings impoundment and the engineering design methods necessary to control such erosive forces. Sheet erosion is defined as that erosion which occurs as a result of the impact of raindrops striking the ground surface or water flowing in small ephermal rills. The amount of sheet erosion that can occur at a given location depends on the slope of the land, nature of the cover material, type and density of the cover material, and rainfall duration and intensity.

Control of sheet erosion can be accomplished by grading the cover to gentle, flat slopes and placing gravel, cobbles, or rock layers over the cover, or coarse gravel mixed with finer soil. Such controls can be considered to duplicate desert landforms that have been stable for thousands of years and are described as desert pavements or gravel armor. The design of such controls is quite site specific, however, as emphasized by Nelson, et al. (Ne83).

Gully erosion is caused by concentrated water flowing over the tailings that can cut deep channels through embankments or cover materials and disperse tailings downstream. Gullies can also be initiated off the tailings area and mitigate upstream into the tailings. The formation of gullies depends on topographical features, such as slope angle and slope length, the existence of stable base levels on or near the site, erodibility of the soil, and the flood flow velocity.

Control of gully erosion is best provided by prevention of gully initiation. Topographical features can be altered by providing gentle and shorter slopes, gradual changes in grade, and establishing base levels around the site (rock trenches, wing walls, etc.). Soil erodibility can be reduced by providing larger grained soils (gravel) and/or natural vegetation. Flood flow velocity can be reduced or eliminated by providing diversion ditches. Gentle and short slopes can also reduce this velocity. Depending on a given site's features, it is likely a combination of these controls will be required.

Wind erosion is caused by suspension of small particles in the air and by creep of particles moving along the ground surface. Materials most highly susceptible to wind erosion are fine-grained non-cohesive sands and silts with diameters in the range of 0.02 to 0.10 mm. Particles less than 0.002 mm, which are classified as clays, are highly resistant to wind erosion due to cohesion.

Control of wind erosion can best be accomplished by increasing surface roughness through vegetation and different rock sizes. Measures taken to control water sheet erosion generally should minimize losses by wind erosion.

Differential settlement is not erosion itself but can initiate erosion by channelizing runoff. It can also cause failures by cracking of cover material and by impounding water in depressions. Factors which cause differential settlement include differences in compressibility between different grain sizes of tailings, non-uniformity of tailings in the impoundment, and variation in compressibility of underlying materials.

Controls for differential settlement are surcharging and grading. Surcharging involves placing more cover material than necessary over compressible materials to cause a known amount of settlement within the material. Grading also places additional cover over compressible materials, where differential settlement is not expected to be great.

3.3.4 Floods and Other Natural Processes

Natural processes that can destroy the integrity of disposed tailings piles include floods, winds, and earthquakes. Floods are probably the greatest hazard to integrity. Methods are available to protect piles against floods. New piles can be located so as to minimize disruptions from floods and winds. For existing and new piles, diversion ditches and embankments can be constructed, rocks can be placed on the slopes of piles (and on top if needed), and the tailings can be graded to gradual slopes. Existing piles can also be moved if sufficient protection is not afforded by these methods. These are all passive controls.

The time over which controls should be effective is an important factor in standards for long-term protection. Specifying this time directs the design of disposal methods that have reasonable assurance of providing such effectiveness over this period. The design of a tailings disposal method is similar to the design of other major projects, such as dams, bridges, causeways, etc., that are subjected to natural disruptive processes (Ju83) (Ne83) (Co78).

The first design step is to determine the size of the flood that will be used in the design of the disposal method. This is accomplished by a probabilistic analysis. For example, a flood of a certain magnitude will occur periodically, i.e., a 100-year flood is defined as a flood that has a recurrence rate of 1/100 each year, or 0.01 in any one year. The probability that a 100-year event (flood) will occur sometime during a 100-year period is 0.63, as is the probability that a 1000 year event (flood) will occur sometime during a 1000 year period. Thus, the probability is high that an event with a recurrence time equal to the period of concern will occur within the period of concern.

However, the recurrence time becomes very long for low probabilities, regardless of the period of concern. (The recurrence time defines the size, or design, of the event (flood), i.e., a recurrence time of 10,000 year flood.) For example, for a probability of 5 percent the design event is 2000 years for a 100-year period of concern, is almost 10,000 years for a 400-year period of concern, and is 20,000 years for a 1000-year period of concern. Thus, specifying the period of concern (or the period over which protection must be provided) determines the size of the event (flood) for design purposes, given some reasonably low probability that the event will occur within the period of concern.

The long recurrence times of these design floods preclude the use of historical data, which are of too short a duration. Rather, the design is based on the probable maximum flood (PMF), which in turn is determined from the probable maximum precipitation (PMP) over the area that could effect the disposed tailings. It is important to recognize that the size of flood is not proportioned, in general, to the length of the period of concern. That is, in most cases the PMF is not significantly larger than projections of floods for only moderately long periods of concern (e.g., 1000-year floods). Nelson, et. al. (Ne83), discuss this in detail, especially in regard to size of the drainage basin contributing to the PMF at specific sites. They conclude, "To provide for a level of risk consistent with normal engineering practice for 200, 500, or 1000-year stability periods requires a design storm having a recurrence interval of several thousand years. Because the PMP is based on site specific physical meteorological limitations which avoid the inaccuracies associated with extending limited data bases for long time periods, it is reasonable and prudent to use a PMF based on the PMP as the design flood."

3.3.5 Time Period Considerations in this Analysis

Based on the above discussions, we found it necessary to choose a time period for evaluating the effectiveness of controls. A relatively short time period of about 100 years was considered first since this was proposed as the limit for reliance on institutional controls (EPA78). We concluded that this time period was of little use since both passive controls and active controls, assuming 100-year institutional contol, maintained their initial effectiveness for the entire period.

A period of about 1,000 years appeared more reasonable for evaluating the effectiveness of controls and was selected. Actually this 1,000 year period can be considered to range from a few hundred years to a few thousand years, depending on individual site characteristics. This selection allows the decision makers to choose from a much broader array of options than just the difference between active and passive controls. This is due to the expected variation of the effectiveness of controls over the longer time period.

In general, the effectiveness of controls over time can be rated from best to least as follows:

BEST o Deep geological disposal

o Below-grade surface disposal

o Above-grade surface disposal, entire area covered with thick earth and rock cover

o Above-grade surface disposal, entire area covered with thick earth and slopes covered with rock cover

o Above-grade surface disposal covered with thick earth

LEAST o Above-grade surface disposal with thin earth and maintained

This ranking assumes the tailings pile is located where erosion occurs. If tailings are located where soil deposition is taking place, the assessment will differ significantly as long as deposition continues.

REFERENCES FOR CHAPTER 3

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Ju83 Junge, R. W., "An Analysis of Control Standards for the Long-Term Contaminant of Uranium Tailings," Transcripts of Public Hearings on EPA's Proposed 40 CFR 192 Rules, Denver, June 1983.

Ne83 Nelson, J. D., Volpe, R. L., Wardwell, R. E., Schumm, S. A., and Staub, W. P., "Design Considerations for Long-Term Stabilization of Uranium Mill Tailings Impoundments," Colorado State University, Report to U.S. NRC, August 1983.

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NRC80 Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, 1980.

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Ro83 Rogers, V. C., Personal communication, 1983.

4. Benefit-Cost Analysis

4.1 Overview

This chapter formulates several alternative standards for regulatory analysis. Each alternative represents a different combination of regulatory controls which would be required to meet the objectives of the standard discussed in the previous chapter. Once these alternatives are determined, we then present two analytical methods of quantitatively evaluating the benefits and costs of each alternative. The first method relates the disposal costs for each alternative to the health effect estimates from radon emanating from the tailings piles. Although this analysis relates only one category of benefit to the entire cost of disposal, it attempts to determine if the benefits of control are greater than the cost of control. In the second benefit-cost methodology, we develop a weighted index of all categories of benefits and estimate the relative effectiveness of the assumed engineering control methods in providing the different types of benefits for each alternative standard. We then relate the tailings disposal costs of each alternative standard to the estimated value of this index, to determine, in a relative sense, the changes in cost required for alternative control levels. Both analyses are performed on a model pile basis, done separately for existing tailings and new tailings piles.

4.2 Formulation of Alternative Disposal Standards and Selection of Control Methods

Based on the public comment of the proposed standards, we have reformulated the alternative disposal standards and increased the number of alternatives to be considered. Three types of alternative controls are examined in combination with five levels of radon emission control. These three alternative controls are active control of tailings for a period of 100 years, a 1000-year longevity requirement for passive control, and the 1000-year longevity requirement together with radon control during mill operation for new tailings piles. The five levels of radon emission control after disposal, expressed in terms of pCi/m^2s, are no requirement, 60, 20, 6 and 2. Thirteen different combinations of controls have been formulated as alternative standards and these are displayed in matrix form in Table 4.1. Alternative A is the no control case. Alternatives B1, B2 and B3 combine the active control for 100 years requirement with three levels of radon emission control - no control, 60 and 20 pCi/m^2s, respectively. Alternatives C1 through C5 combine the passive 1000-year longevity requirement with all five levels of radon emission control after disposal. Alternatives D2 through D5 combine the radon control requirement during operations for new piles, plus the 1000-year longevity requirement for all piles, with four levels of radon control after disposal. Under Alternative D, the controls for disposal of existing piles would be the same as under Alternative C for the respective level of radon emission control (level 2 through 5).

Table 4.1. Alternative Standards - Combinations of Regulatory Controls

Other Controls	Radon Control after Disposal (pCi/m^2s)				
	No Radon Requirement	60	20	6	2
No Controls	A				
Active control for 100 years	B1	B2	B3		
Passive control for 1000 years	C1	C2	C3	C4	C5
1000-year passive longevity, plus radon control during operations for new piles		D2	D3	D4	D5

These alternatives thus consider both active and passive control of mill tailings and several different levels of radon control. Although Alternative D adds a non-disposal requirement - radon control during mill operations - the effect of this operations requirement influences the selection of the tailings disposal method, as described below.

For each set of alternative standards (B, C and D), we have selected a disposal technique which we assume for analytical purposes will be necessary for compliance. All of these disposal techniques represent, in some degree, undemonstrated technology since none of the tailings piles has yet been disposed, and the predictability of performance over the long term is not well established. Within each set of alternative standards, the disposal technique remains the same for each level of radon control after disposal. However, the thickness of the earth cover required does change in order to comply with each radon control level.

In Alternatives B1, B2, and B3, we assume that active control methods will provide compliance with the standards. These methods include maintenance of the earth cover and fence, and irrigation of the vegetative cover for 100 years. The sides of the pile are graded to a 3:1 (H:V) slope while the top of the pile is landscaped. Earth cover thicknesses of 0.5, 1.5, and 2.4 meters are assumed for compliance with the three different radon control levels. A fence is constructed around the pile after allowing 0.5 km from all sides for an exclusionary zone.

For Alternatives C1 through C5, we assume that the passive control method of rock cover on the slope plus an earth cover including a 0.5 meter layer of pebbly soil on top of the pile will provide compliance with the 1000-year longevity requirement. The amounts of earth cover required to attenuate the radon assumed for these methods are the same as in Alternatives B and D, as the layer of pebbly soil on top just replaces the last 0.5 meter of earth cover. The earth cover thicknesses are 0.5, 1.5, 2.4, 3.4, and 4.3 meters for alternatives C1 through C5, respectively. The sides of the pile are graded to a 5:1 (H:V) slope and no fence is needed.

Under Alternatives D2 through D5, control of radon during mill operations is assumed to be met by requiring staged disposal of tailings below grade. Two pits are constructed initially with tailings pumped to the first pit until it is full and then pumped to the second pit. When the first pit is sufficiently dry, the third or fourth pit is excavated, with the excavated earth used to cover the first pit to the original ground contour. This process continues sequentially until the end of mill life and thus minimizes the time over which tailings will be uncovered. The earth cover thicknesses required are 1.5, 2.4, 3.4, and 4.3 meters for Alternatives D2 through D5. As stated earlier, this control method is applicable to a new pile only. However, if the radon requirement during operations is directed at existing mills, the result may be that future tailings generated at that mill may have to be placed in a new impoundment designed for staged disposal. Chapter 5 discusses the economic impacts of this alternative.

Tables 4.2 and 4.3 summarize the characteristics of each control method for existing and new piles, respectively. The FEIS contains a more detailed description of the control methods.

4.3 Cost Analysis

We developed disposal cost estimates for each control method on a model pile basis. We have made conservative assumptions for these cost estimates, so as to accommodate the uncertainties of performance that must be considered to provide "reasonable assurance" of conformance to the standards. The reader should refer to the FEIS for a detailed explanation on the development of the model pile cost estimates.

For existing tailings, we developed the disposal cost estimates for three model-sized piles. As of January 1983, there were 26 licensed uranium mills with tailings piles. An analysis of these piles indicates that they vary widely in size and, thus, control costs would vary greatly. Consequently, we grouped the existing piles into model piles as follows:

a. 2 million ton pile on 122 acres with an average depth of 2.20m
No. of piles in this group = 11
Average tons per pile = 1.9 million
(Range = 0.0 to 3.2 million tons)
Average area covered = 122 acres
(Range = 47 to 200 acres)

b. 7 million ton pile on 180 acres with an average depth of 5.64 m
No. of piles in this group = 12
Average tons per pile = 7.2 million
(Range = 4.5 to 10.9 million tons)
Average area covered = 180 acres
(Range = 85 to 400 acres)

c. 22 million ton pile on 279 acres with an average depth of 11.25 m
No. of piles in this group = 3
Average tons per pile = 22.5 million
(Range = 19.2 to 27.6 million tons)
Average area covered = 279 acres
(Range = 210 to 328 acres)

For new tailings piles, we developed cost estimates for a single model pile. This model pile is based on the quantity of tailings generated by NRC's model mill in their GEIS (NRC80). The NRC model mill has an ore-processing capacity of 1,800 MT per day. The ore grade is expected to average 0.1% uranium and the uranium recovery efficiency is assumed at 93%. The mill is operated 310 days per year (i.e., 85 percent capacity utilization rate) and the average annual production is 580 MT yellowcake which is 90% U_3O_8. The tailings will be generated at a rate of 1,800 MT per day, or 558 thousand MT per year, or 8.4 million MT during the assumed 15 year operating period of the mill. The tailings cover an area of 80 ha with earth embankments around the tailings bringing the total area to 100 ha. The depth of tailings is about 8 meters.

Table 4.2. Alternative Standards and Control Methods - Existing Piles

		Control Method Characteristics					
Alternative Standard	Control Method Designation	Earth Cover Thickness (m)	Slope	Rock on Slopes	.5m Pebbly Soil on Top	Maintenance	Landscaping
A	-						
B1	B1-E	0.5	3:1			100 years	X
B2	B2-E	1.5	3:1			100 years	X
B3	B3-E	2.4	3:1			100 years	X
C1	C1-E	0.5	5:1	X	X		
C2	C2-E	1.5	5:1	X	X		
C3	C3-E	2.4	5:1	X	X		
C4	C4-E	3.4	5:1	X	X		
C5	C5-E	4.3	5:1	X	X		
D2	Same as C2						
D3	Same as C3						
D4	Same as C4						
D5	Same as C5						

Table 4.3. Alternative Standards and Control Methods - New Piles

		Control Method Characteristics							
Alternative Standard	Control Method Designation	Earth Cover Thickness (m)	Slope	Rock on Slopes	.5m Pebbly Soil on Top	Maintenance	Put Below Grade	Liner	Landscaping
A	A-N	Construction of initial embankments only							
B1	B1-N	.5	3:1			100 years		X	X
B2	B2-N	1.5	3:1			100 years		X	X
B3	B3-N	2.4	3:1			100 years		X	X
C1	C1-N	.5	5:1	X	X			X	
C2	C2-N	1.5	5:1	X	X			X	
C3	C3-N	2.4	5:1	X	X			X	
C4	C4-N	3.4	5:1	X	X			X	
C5	C5-N	4.3	5:1	X	X			X	
D2	D2-N	1.5					X	X	X
D3	D3-N	2.4					X	X	X
D4	D4-N	3.4					X	X	X
D5	D5-N	4.3					X	X	X

The total cost and unit cost for each control method and model pile are displayed in Table 4.4.

4.4 Benefits Analysis

The benefits of each control method are the degree to which each of the goals of the standards is achieved. Most of the benefits are health-related (erosion prevention avoids contaminating land, and therefore affects land use). While some can be quantified in terms of health risk, others cannot. The benefit we are best able to estimate is the number of lung cancer deaths averted by radon control. We can estimate the reduction in radon emissions resulting from the placement of earth covers and then translate the radon emissions reduction into lung cancer deaths averted by using models for radon inhalation. The other benefits from tailings disposal are not quantifiable since we do not know what would take place in the absence of the environmental control. Consequently, the incremental benefit of the control cannot be estimated. While we cannot quantify these benefits, we nevertheless can qualitatively discuss the likelihood that these control methods may provide protection and the length of time over which they are expected to remain effective. Several measures of the benefits of control of mill tailings have been developed. The benefits provided by each disposal method are discussed in-depth in the FEIS which accompanies this RIA. Table 4.5 summarizes these benefit measures.

The benefit of prevention of misuse is expressed in terms of the likelihood that misuse might occur. The likelihood of misuse during the period of effectiveness of these methods ranges from very likely for the no control case (A) to very unlikely for the methods requiring 3 or more meters of earthen covers (C4, C5, D4, and D5).

The benefit of prevention of surface spread of tailings is expressed on the basis of the number of years over which erosion of the tailings is prevented. Erosion prevention is estimated to range from 100 years for the one-half-meter earth cover (B1) to many thousands of years for the below-grade methods requiring greater than 3-meter earthen covers.

The benefits of radon control are estimated in terms of the total number of lung cancer deaths which are avoided and the maximum lifetime lung cancer risk to an individual living close to the pile. The total lung cancer death rate from radon emissions from existing tailings piles at active mill sites is estimated to be about 19 deaths per century for each pile if no controls are used. For new piles, we estimate the lung cancer death rate to be 13 deaths per century for each new pile. This estimate is lower than the average for the existing piles since we believe that new mills in the future will be located, on average, in less populated areas than they have in the past. The FEIS presents the basis for these estimates. The standard alternatives requiring a 20 pCi/m^2s emission limit and a 1000-year longevity requirement (C3 and D3) would

Table 4.4. Disposal Cost Summary for Model Piles[a]

Control Method	Total Cost (Millions of 1983 $)			Unit Cost ($/MT of Tailings)		
Existing Tailings Piles:	Model Pile Size (MT)			Model Pile Size (MT)		
	2	7	22	2	7	22
B1-E	4.2	6.4	10.8	2.10	0.91	0.49
B2-E	6.9	10.4	17.3	3.45	1.49	0.79
B3-E	9.2	14.0	23.0	4.60	2.00	1.05
C1-E	3.2	6.3	13.6	1.60	0.90	0.62
C2-E	5.9	10.5	20.6	2.95	1.50	0.94
C3-E	8.3	14.3	26.8	4.15	2.04	1.22
C4-E	10.9	18.5	33.8	5.45	2.64	1.54
C5-E	13.3	22.2	40.0	6.65	3.17	1.82

New Tailings Piles:	Model Pile Size (MT)	Model Pile Size (MT)
	8.4	8.4
A	1.3	0.15
B1-N	22.9 (11.4)	2.73 (1.36)
B2-N	26.5 (15.0)	3.15 (1.79)
B3-N	30.5 (19.0)	3.63 (2.26)
C1-N	22.9 (11.4)	2.73 (1.36)
C2-N	27.5 (16.0)	3.27 (1.90)
C3-N	31.5 (20.0)	3.75 (2.38)
C4-N	35.8 (24.3)	4.26 (2.89)
C5-N	39.9 (28.4)	4.75 (3.38)
D2-N	40.4 (32.3)	4.81 (3.85)
D3-N	43.6 (35.5)	5.19 (4.23)
D4-N	47.6 (39.5)	5.67 (4.70)
D5-N	51.2 (43.1)	6.10 (5.13)

(a)Cost estimates in parentheses exclude the cost of a liner which provides groundwater protection during the operational phase of a tailings pond.

Table 4.5. Benefits of Alternative Standards for Tailings Control(a)

Alternative Standards	Stabilization		Radon Control			Water Protection
	Chance of Misuse	Erosion Avoided (years)	Maximum Risk(b) of Lung Cancer (% reduction)	Deaths Avoided Per Pile(c) First 100 years	Deaths Avoided Per Pile(c) 1000 Years	Longevity (years)
A	Very likely	0	2 in 10^2(0)	0	0	0
B1	Likely	Hundred	1 in 10^2(50)	7-10	26-38	100
B2	Less Likely	Hundreds	4 in 10^3(80)	10-15	39-57	100
B3	Less Likely	Hundreds	1 in 10^3(95)	12-18	46-67	100
C1	Likely	Hundred	1 in 10^2(50)	7-10	65-95	100
C2	Less Likely	Thousands	4 in 10^3(80)	10-15	104-152	100's
C3	Unlikely	Thousands	1 in 10^3(95)	12-18	124-181	1000
C4	Very Unlikely	Many thousands	3 in 10^4(98.5)	13-19	128-187	>1000
C5	Very Unlikely	Many thousands	1 in 10^4(99.5)	13-19	129-189	>1000
D2	Unlikely	Thousands	4 in 10^3(80)	10	104	1000
D3	Unlikely	Many thousands	1 in 10^3(95)	12	124	1000
D4	Very unlikely	Many thousands	3 in 10^4(98.5)	13	128	>1000
D5	Very unlikely	Many thousands	1 in 10^4(99.5)	13	129	>1000

(a) The estimates of benefits assume no credit for engineering factors required to provide "reasonable assurance" of design compliance for the specified radon control level and period of longevity.

(b) Lifetime risk of fatal cancer to an individual assumed to be living 600 meters from the center of a model tailings pile.

(c) The lower end of the range for Alternatives B and C pertains to a model new pile, while the higher number pertains to the average for the 26 existing tailings piles. The estimates for Alternative D apply to new piles only. In the FEIS, we estimate that there will be about 500 radon deaths per century for all existing tailings if no disposal actions are taken. This results in an average of 19 deaths per century for each existing pile. We further estimate that there will be 116 additional radon deaths per century from the 9 new-pile-equivalents projected to be generated by the year 2000, if the tailings are left uncontrolled. This results in an average of 13 deaths per century for each new-pile-equivalent. Approximately one-half of the estimated deaths occur in the region surrounding the site (as defined in the FEIS), while the other half occurs throughout the nation. The control methods chosen for Alternatives C and D are assumed to maintain their initial degree of effectiveness for the entire 1000-year period. The effectiveness of Alternative B is assumed to decrease after the 100-year maintenance period ends, and the average percentage reductions from the uncontrolled case over the 1000-year period have been estimated for Alternatives B1, B2, and B3 as 20, 30, and 35 percent, respectively.

reduce this rate to about 1 death per century for both existing and new piles. The benefit from a 2 pCi/m^{2}s limit (C5 and D5) would be the virtual elimination of the radon risk. The lifetime risk to the individual living close to the edge of the pile is estimated to be 2 in 100 for an uncontrolled tailings pile. This risk is reduced to 1 in 1,000 for a 20 pCi/m^{2}s emission limit and 1 in 10,000 for a 2 pCi/m^{2}s limit.

The benefit of protecting groundwater is the preservation of its existing quality for future uses. The great majority of the potential contamination of groundwater is the result of process fluids which are discharged to the tailings pond during the operating life of the mill. This potential contamination can be prevented by either the installation of a liner (before tailings are generated) or the selection of a disposal site with favorable geological and hydrological characteristics. Groundwater contamination may also occur after disposal of tailings if precipitation infiltrates the tailings and then enters an aquifer. As discussed in Chapter 3, groundwater protection after disposal is provided by the earthen cover placed over the tailings. The benefit of groundwater protection is measured by the number of years over which the cover is expected to prevent contamination. This benefit is estimated to range from 100 years for the active maintenance disposal methods (B) to greater than 1000 years for the methods requiring a greater than 3-meter earthen cover. Groundwater protection during the operational phase of a tailings pond is covered by the proposed operations standards and, therefore, is not addressed in this benefits analysis.

One benefit which is not presented in Table 4.5 is the reduction in radon emissions from tailings piles during the operational period of a mill associated with Alternative D. This alternative assumes a staged-disposal system below-grade, which will reduce the amount of time that tailings remain uncovered and, thus, reduce the cumulative amount of radon emissions. We do not have sufficient information on the effectiveness, feasibility and costs of alternatives that would control releases from operating mills to include this issue in our benefit-cost analysis. As stated in Chapter 1, we are preparing an Advanced Notice of Proposed Rulemaking to attempt to collect this information for purposes of future rulemaking on this issue. We have analyzed the staged disposal method for its benefits as a long-term disposal system, but we point out that it has other benefits associated with its use.

4.4.1 Radon Control Benefits Versus Disposal Costs

Since the radon control benefits are the only benefits that we can quantify, we have compared the disposal cost for each method to the number of deaths avoided to gain some insight as to the level of benefits associated with control expenditures. Since radon control is just one of several benefits to be realized from control of tailings, the results of this limited benefit-cost comparison can be viewed as determining the minimum level of benefits which is obtainable. Table 4.6 shows for each disposal method deaths avoided for 1000 years and the tailings disposal

Table 4.6. Radon Control Benefits Versus Disposal Cost

Control Method	Deaths Avoided for 1000 Yrs per pile(a)	Model Pile Disposal Costs(b) (10^6 1983 $)	Average Cost Per Death Avoided (10^6 1983 $)	Incremental Cost Per Death Avoided (10^6 1983 $)
Existing Tailings (7 million MT pile):				
A	0	0	-	-
B1	38	6.4	.17	.17
B2	57	10.4	.18	.21
B3	67	14.0	.21	.36
C1	95	6.3	.07	.07(c)
C2	152	10.5	.07	.07
C3	181	14.3	.08	.13
C4	187	18.5	.10	.63
C5	189	22.2	.12	1.95
New Tailings:				
A	0	1.3	-	-
B1	26	11.4	.44	.39
B2	39	15.0	.38	.28
B3	46	19.0	.41	.57
C1	65	11.4	.18	.15(c)
C2	104	16.0	.15	.12
D2	104	32.3	.31	(d)
C3	124	20.0	.16	.21
D3	124	35.5	.29	(d)
C4	128	24.3	.19	.93
D4	128	39.5	.31	(d)
C5	129	28.4	.22	3.15
D5	129	43.1	.33	(d)

(a) These estimates are rounded to the nearest whole number. In performing the incremental cost per death avoided calculation, the estimates of deaths avoided were carried to a few decimal places to allow for a more accurate comparison of the incremental cost of each control method.

(b) Excludes cost of liner for groundwater protection during operational phase of mill.

(c) Incremental costs and deaths avoided measured from Method A.

(d) No measurable incremental (post-disposal) radon health benefit from previous method, but other incremental benefits, such as prevention of misuse and control of radon during mill operation, are realized.

cost, both estimated on a model pile basis. (We recognize that this analysis ignores benefits beyond 1000 years for some cases.) This benefit-cost comparison is done for the model new tailings pile and medium-sized model existing tailings pile.

The disposal methods are listed in ascending order of the number of deaths avoided by radon control, and both the average and incremental cost per death avoided is shown for each method. The average cost is simply the ratio of the disposal cost to the total number of deaths avoided. The incremental cost is the ratio of the change in disposal cost to the change in deaths avoided from the previous disposal method. EPA has estimated from studies of market compensation for small changes in workers' risks that people would be willing to pay from 0.4 to 7.0 million dollars to save a statistical life, at the margin (ERC83). Upon examining the average cost estimates in Table 4.6, we see that all control methods fall below the lower end of the empirical range. A more appropriate measure of the benefit-cost tradeoffs of the alternative disposal methods is the incremental changes in costs and benefits. The estimates of incremental cost per death avoided by radon control indicate that all control methods for both existing and new tailings piles fall below the $7 million upper end of the empirical range. The incremental cost remains relatively constant at $100,000-200,000 per death avoided through control method C3, then increases by a factor of 5 to about $600,000-$900,000 per death avoided for control method C4, and then increases by a factor of 3 to about $2-3 million per death avoided for control method C5.

There are several limitations to this type of benefit-cost comparison. A major limitation is the determination of the time period over which the deaths avoided should be estimated. Since the mill tailings remain hazardous for thousands of years, the benefits of control are also realized for thousands of years or as long as the control method remains effective. The computational problems of estimating cost per death avoided are evident. The longer the time period considered, the more favorable the ratio becomes. A related issue is how the future stream of benefits should be related to costs which are incurred all at once at time of disposal. Should the present value of benefits and costs be used or not? Another limitation of this type of analysis is that the empirical range of the value of a statistical life is based on people's estimates of the value of reductions in relatively small risk activities and not a direct estimate of the value of life. Therefore, the application of this estimated range of life valuation to regulations concerning human health effects may be questionable. Another limitation is the degree of uncertainty in the radon death estimates. The FEIS explains the estimation procedure for the deaths avoided and the sources of uncertainty. Lastly, this benefit-cost comparison only covers one category of benefits and, therefore, ignores the attainment of other benefits for the same expenditure.

To address the first limitation, we have estimated the incremental cost per death avoided for the alternative radon emission limits (C1 through C5) under four different sets of assumptions. By examining these different incremental cost estimates, one can gain more perspective on under what set of conditions does a level of control become acceptable. These different cases are as follows:

- Nationwide deaths avoided over a period of 1000 years (Table 4.6)
- Regional deaths avoided over a period of 1000 years
- Nationwide deaths avoided over a period of 100 years
- Regional deaths avoided over a period of 100 years

A comparison of the incremental costs for each control level under these scenarios is presented graphically in Figure 4.1 for the medium-sized model existing pile. Also highlighted on this figure is the .4 to 7 million dollar empirical range for expenditures per statistical life. The results of this display indicate that Alternative Standards C1, C2, and C3 fall below the upper end of this range for every scenario. The incremental cost per death avoided for Alternative C4 (6 pCi/m^{2}s) is within the range for three of the scenarios, but is significantly higher for the regional health effects - 100 year case. Alternative C5 is within the range when estimates of nationwide or regional deaths for 1000 years are used. As the curves further indicate, the incremental cost increases substantially in a relative sense once one goes beyond C3 to C4. Although it is difficult to interpret these data, a few conclusions can be made. First, radon control as far as 20 pCi/m^{2}s is justified on benefit-cost grounds over a variety of conditions. Second, control to 6 pCi/m^{2}s may or may not be justified according to one's view on what health factors should be considered. Also, on a relative basis, C4 is about 5 times as costly as C3.

4.4.2 Effectiveness Index

Even if each of the benefits could be quantified in some manner, there still would be no common numerical basis for expressing each estimation. To perform a benefit-cost analysis of disposal methods, there is a need for an expression of the combined benefit of each method. While we cannot quantify these benefits, we believe that we can quantify, on a relative basis, the effectiveness of disposal methods in providing each of the classes of control. This quantification of the effectiveness of disposal methods can serve as a gauge for the benefits estimation. To meet this need, we have developed an effectiveness index which provides a numerical measure of the overall effectiveness (or benefit) of each disposal method.

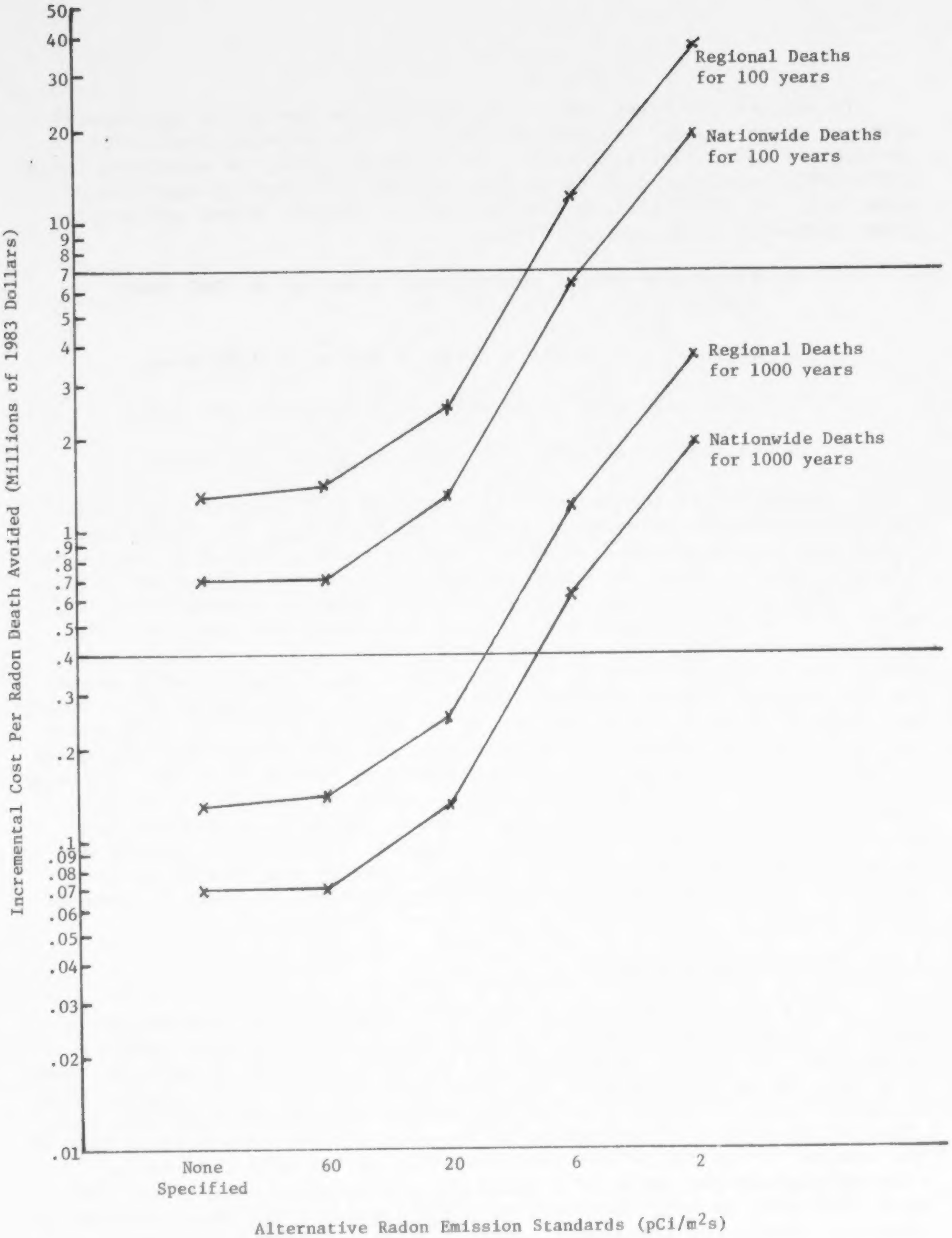

Figure 4.1. Incremental Cost per Radon Death Avoided for Alternative Standards

The formulation of the effectiveness index depends on (1) the relative effectiveness of disposal methods in achieving each class of control; and (2) judgmental weighting factors for each control class. For each tailings disposal method (see Table 4.3), a rating from zero to ten is assigned for each of the control classes. The rating corresponds to the degree of effectiveness of the disposal method in providing the control; zero represents no effectiveness, while ten stands for 100 percent effectiveness. Independently, each of the control classes must be assigned a weighting factor. This requires a judgment on the relative importance of each of the goals of the standards when compared with one another. After the numerical weights are established, a weighted average effectiveness index for each disposal method is calculated.

This estimation procedure yields a single measure of the overall benefit of each disposal method. The remainder of this section explains in detail how the effectiveness index is calculated and describes the assumptions upon which it is based.

The disposal methods are rated for their likelihood of effectively providing each of the classes of control for approximately 1000 years duration. Due to the long time period, we have relied heavily on our judgment in developing these ratings. Much of this judgment has already been discussed in Chapter 3. Although these ratings may be questioned when viewed in an absolute sense, we feel that they have more validity when viewed in a relative sense. For example, it is extremely difficult to estimate how effective a 1-meter earth cover is in preventing misuse for 1000 years. However, we can be certain that a 3-meter earth cover has a greater likelihood of preventing misuse than a 1-meter cover. It is in this relative sense that the effectiveness index is used in this RIA.

Table 4.7 presents the effectiveness ratings for each disposal method and class of control.

Prevention of Misuse

The basis for the relative rankings of the disposal methods in providing long-term isolation was discussed in Chapter 3. We feel that a thick earth cover plus a substantial rock cover or placement below-grade is necessary to isolate the tailings for 1000 years. Therefore, we rated the methods with 100-year maintenance of the cover as providing only 10 (for B1 and B2) or 20 percent (for B3) effectiveness since, after the maintenance stops, the earth cover will not be effective in preventing misuse over the next 900 years.

The highest rated method was below-grade disposal with the thickest earth cover (4.3 meters - Alternative D5) assigned a rating of 10. Each preceding below-grade alternative (D4, D3, and D2) received a rating one point lower than the succeeding method to reflect the incremental effectiveness of the cover thickness. Therefore, D4 received a 9, D3 an 8, and D2 a 7 rating. Alternatives C1 through C5 were similarly ranked, with C5 assigned a rating of 9 since we believe that, for a given cover

Table 4.7. Effectiveness Index for Control Methods by Class of Control

Control Method	Prevent Misuse	Radon Control	Prevent Spread of Tailings	Water Protection	Weighted Average[a]
A	0	0	0	0	0
B1	1	1	1	1	1.0
B2	1	3	2	1	1.8
B3	2	5	3	2	3.1
C1	4	4	7	3	4.3
C2	6	8	9	5	6.9
C3	7	9	10	6	7.9
C4	8	10	10	6	8.6
C5	9	10	10	7	9.2
D2	7	8	10	5	7.5
D3	8	9	10	6	8.3
D4	9	10	10	6	9.0
D5	10	10	10	7	9.6

(a) The weights for this average are as follows:
I. Prevention of misuse - 40 percent
II. Radon control - 30 percent
III. Prevention of surface spread of tailings - 15 percent
IV. Groundwater protection - 15 percent

thickness, disposal below-grade will be more effective in preventing misuse than disposal above-grade with rock cover. Consequently, ratings of 8, 7, 6, and 4 were assigned to Alternatives C4, C3, C2, and C1, respectively.

Radon Control

The effectiveness ratings for radon control for each alternative are based on the emission limits required by each alternative in relation to the assumed average radioactivity content of tailings piles (400 pCi/m^2s). These percentage reductions in radon emissions are shown for each alternative in Table 4.5. Due to the longevity requirement for Alternatives C and D, we assume that the control of radon emissions will be effective for the entire 1000-year period. Therefore, Alternatives C4, D4, C5, and D5 were rated a 10. Alternatives C3 and D3 were assigned a 9, while Alternatives C2 and D2 received a rating of 8. Alternative C1 was rated a 4. For Alternative B, once the maintenance period is over, we expect that parts of the cover will erode away over time. We assigned Alternatives B1, B2, and B3 ratings of 1, 3, and 5, respectively.

Prevention of Surface Spread of Tailings

As discussed in Section 3.2, the spread of tailings by wind, precipitation and surface water is effectively eliminated by 1 meter of earth. Also, a 1-meter earth cover reduces external gamma radiation to background levels, or to levels caused by the radioactive materials in the cover soil itself. Therefore, disposal methods which are expected to maintain at least a 1-meter cover for 1000 years were rated either a 9 or 10. Alternative C1, with a 0.5-meter cover and rock on the slopes, was assigned a 7. Alternatives B1, B2, and B3, the active maintenance methods, were rated 1, 2, and 3, respectively.

Water Protection

Protection of groundwater from contamination by the process fluids during mill operation is provided by placing a clay or plastic liner between the tailings and the ground surface. Selection of a disposal site in clay soils and at a substantial distance from aquifers can also provide groundwater protection and eliminates the need for a liner. Other methods include promoting runoff of precipitation and minimizing drainage into a tailings pile. However, these other methods are highly dependent on the site characteristics.

After mill operation, groundwater can still be contaminated by precipitation entering the tailings pile and then reaching the groundwater. Surface waters may also become contaminated if the runoff from tailings piles picks up enough hazardous material and reaches bodies of surface water. We estimate that the potential water contamination occuring after mill operation is very slight in comparison to the potential contamination due to the discharge of process fluids. Nevertheless, a thick earthen cover is required to prevent any additional water contamination.

Since we are only concerned in this RIA with water protection after disposal, the effectiveness ratings are based on the thickness of the earth cover. For a given cover thickness, we rated Alternatives C and D equally. Disposal below-grade may maintain the integrity of the earth cover longer than above-grade disposal, but water has a more likely chance of penetrating a pile below-grade than one above-grade which has been designed for run-off. We have assumed that these factors offset each other and, therefore, result in the same ratings for each method. Alternatives C5 and D5 received the highest rating, a 7, while Alternatives C3, C4, D3, and D4 were rated a 6. Alternatives C2 and D2 were assigned a rating of 5, and C1 received a 3. The active maintenance methods were rated a 1 (B1 and B2) or a 2 (B3).

Benefit Weighting Factors

The selection of the weighting factors for the classes of controls is required in order to express a measure of the overall benefit. If all of the health-related objectives of these standards could be stated on a quantitative risk basis, then combining the estimation of individual benefits would be a straight-forward summation of the individual benefits. However, as stated earlier in this chapter, we cannot express each of the benefits in health-risk terms. Therefore, we need an alternative means of combining the benefits.

The benefit weighting factors are a quantitative expression of the relative importance of each class of control. After considering the public comment on the proposed standards, we have changed the numerical weights from those presented in the RIA for the proposed standards. The new weighting factors are as follows:

I. Prevention of misuse - 40 percent

II. Radon control - 30 percent

III. Prevention of surface spread of tailings - 15 percent

IV. Water protection - 15 percent

Two alternative weighting schemes which are different than the one displayed above were also devised and are evaluated in the sensitivity analysis presented in Section 4.4.3.1.

4.4.3 Cost-Effectiveness Analysis

In a broad sense, the purpose in performing a benefit-cost analysis is to direct the allocation of resources in the most efficient way possible. In applying benefit-cost analysis to government regulations, the intent is to ensure that, first, the benefits attributed to the regulation outweigh the costs, and, second, that the proposed form of the regulation yields the greatest net benefit when compared to other regulatory alternatives. Underlying the analysis is the assumption that the benefits can be expressed on a comparable, monetary basis with the costs. In the development of environmental regulations, benefit-cost analysis is often rejected because this monetization of benefits is not feasible. In this section, we employ a modified form of benefit-cost analysis, cost-effectiveness analysis, to determine a level of control for tailings disposal that represents a reasonable balancing of costs and benefits. We do not monetize the benefits, but we do quantify the overall benefit or effectiveness of each disposal method and relate this measure to the total costs in a systematic manner.

The total cost and effectiveness index for each disposal method is presented in Table 4.8 for the three model existing tailings piles and the model new tailings pile. As explained earlier, the liner costs were excluded from the disposal cost estimates used in this analysis since the liner requirement is due to the operations standards and is not part of the tailings disposal system. Similarly, the benefits provided by a liner during the operational phase of the tailings pond have not been considered in this cost-effectiveness analysis. We have only considered the effectiveness of the cover in providing water protection after disposal. The disposal methods are listed in order of ascending value of the effectiveness index. These same data are presented graphically in Figures 4.2 through 4.5.

Upon examining these estimates, it is apparent that some disposal methods are totally dominated by others in that they have both a lower (or equal) effectiveness rating and higher cost. Clearly, one would not select such a method (on the grounds of benefit-cost analysis) when there are others that would provide greater or equal benefit at lower cost. Therefore, these methods are eliminated from further consideration. These methods are represented by the points located below the curves in Figures 4.2 through 4.5.

In Table 4.8, we have calculated the average and incremental costs of each disposal method. The average cost is the ratio of the total cost to the effectiveness index. The incremental cost is the ratio of change in cost from the preceding method to the change in the effectiveness index. The incremental cost measure is the cost of the incremental benefit that each method provides. According to economic theory, we would select the method in which the marginal cost equals the value of the marginal benefit. However, as stated above, we cannot make this determination since the monetary value of the effectiveness index cannot be estimated. Despite the inability to determine the point where marginal cost equals marginal benefit, these data can be used to determine a reasonable level of control.

For the 2 million MT model existing tailings pile, the incremental cost remains relatively constant from C1 to C2, and then more than doubles from C2 to C3. Beyond C3, the incremental cost increases by an additional 50 percent. Control methods B1, B2, and B3 are eliminated from consideration since they are dominated by C1. Method C2 is clearly preferable to C1, while the estimates indicate a noticeable relative cost increase beyond C2. This analysis does not shed any light on whether the cost increases of tighter controls are worth incurring, but rather, it

Table 4.8. Cost-Effectiveness of Control Methods

Control Method	Effectiveness Index	Total Cost (10^6 1983 $)	Average Cost	Incremental Cost
2 million MT Existing Pile				
A	0	0	---	---
B1	1.0	4.2	Eliminated from consideration	
B2	1.8	6.9	Eliminated from consideration	
B3	3.1	9.2	Eliminated from consideration	
C1	4.3	3.2	.7	.7
C2	6.9	5.9	.9	1.0
C3	7.9	8.3	1.1	2.4
C4	8.6	10.9	1.3	3.7
C5	9.2	13.3	1.4	4.0
7 million MT Existing Pile				
A	0	0	---	---
B1	1.0	6.4	Eliminated from consideration	
B2	1.8	10.4	Eliminated from consideration	
B3	3.1	14.0	Eliminated from consideration	
C1	4.3	6.3	1.5	1.5
C2	6.9	10.5	1.5	1.6
C3	7.9	14.3	1.8	3.8
C4	8.6	18.5	2.2	6.0
C5	9.2	22.2	2.4	6.2
22 million MT Existing Pile				
A	0	0	---	---
B1	1.0	10.8	10.8	10.8
B2	1.8	17.3	Eliminated from consideration	
B3	3.1	23.0	Eliminated from consideration	
C1	4.3	13.6	3.2	0.8
C2	6.9	20.6	3.0	2.7
C3	7.9	26.8	3.4	6.2
C4	8.6	33.8	3.9	10.0
C5	9.2	40.0	4.3	10.3

Table 4.8. Cost-Effectiveness of Control Methods (cont.)

Control Method	Effectiveness Index	Total Cost (10^6 1983 $)	Average Cost	Incremental Cost
8.4 million MT New Pile				
A	0.0	1.3	---	---
B1	1.0	11.4	Eliminated from consideration	
B2	1.8	15.0	Eliminated from consideration	
B3	3.1	19.0	Eliminated from consideration	
C1	4.3	11.4	2.7	2.3
C2	6.9	16.0	2.3	1.8
D2	7.5	32.3	Eliminated from consideration	
C3	7.9	20.0	2.5	4.0
D3	8.3	35.5	Eliminated from consideration	
C4	8.6	24.3	2.8	6.1
D4	9.0	39.5	Eliminated from consideration	
C5	9.2	28.4	3.1	6.8
D5	9.6	43.1	4.5	36.8

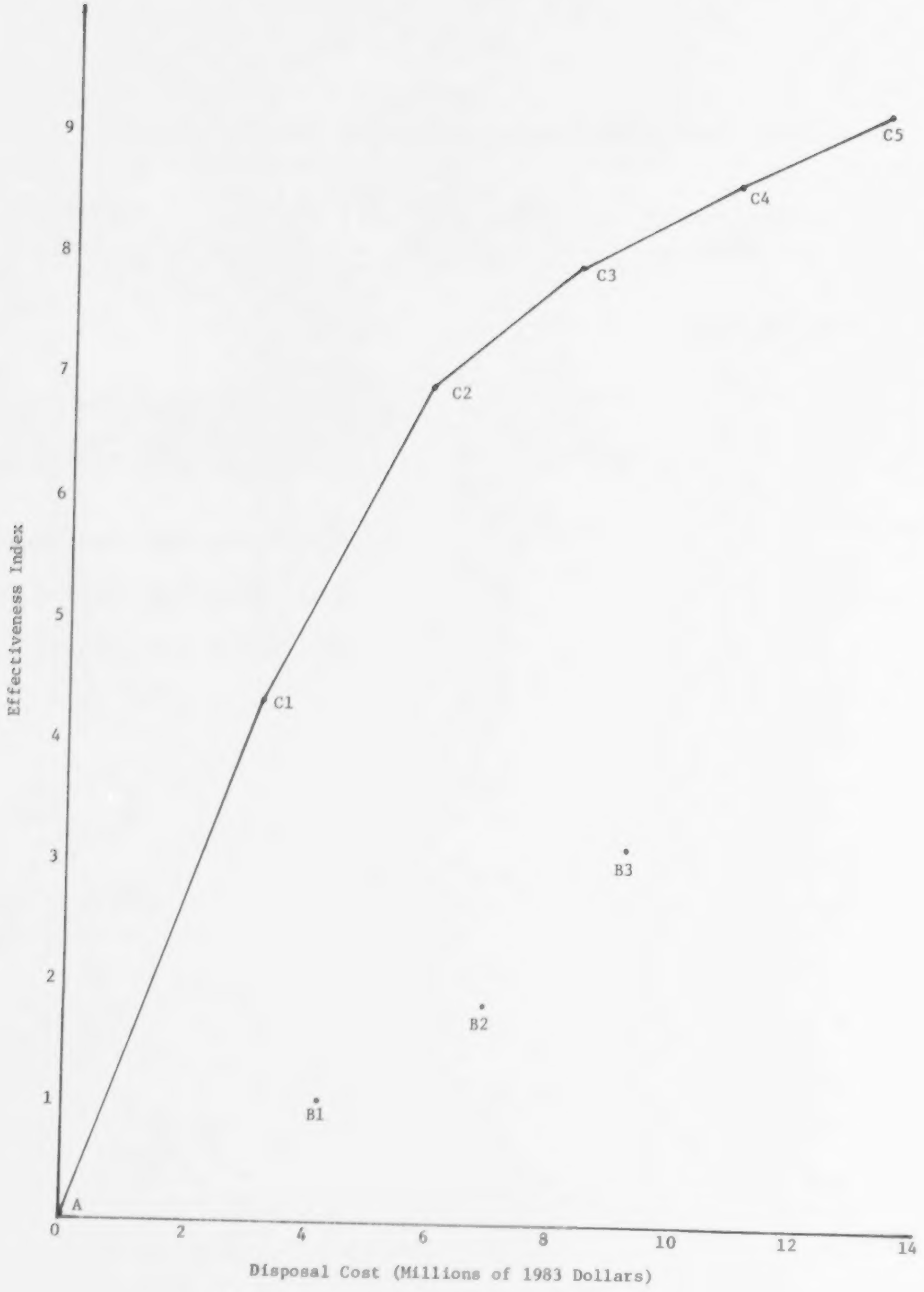

Figure 4.2. Cost-Effectiveness of Control Methods - Existing Tailings, 2 Million MT Pile

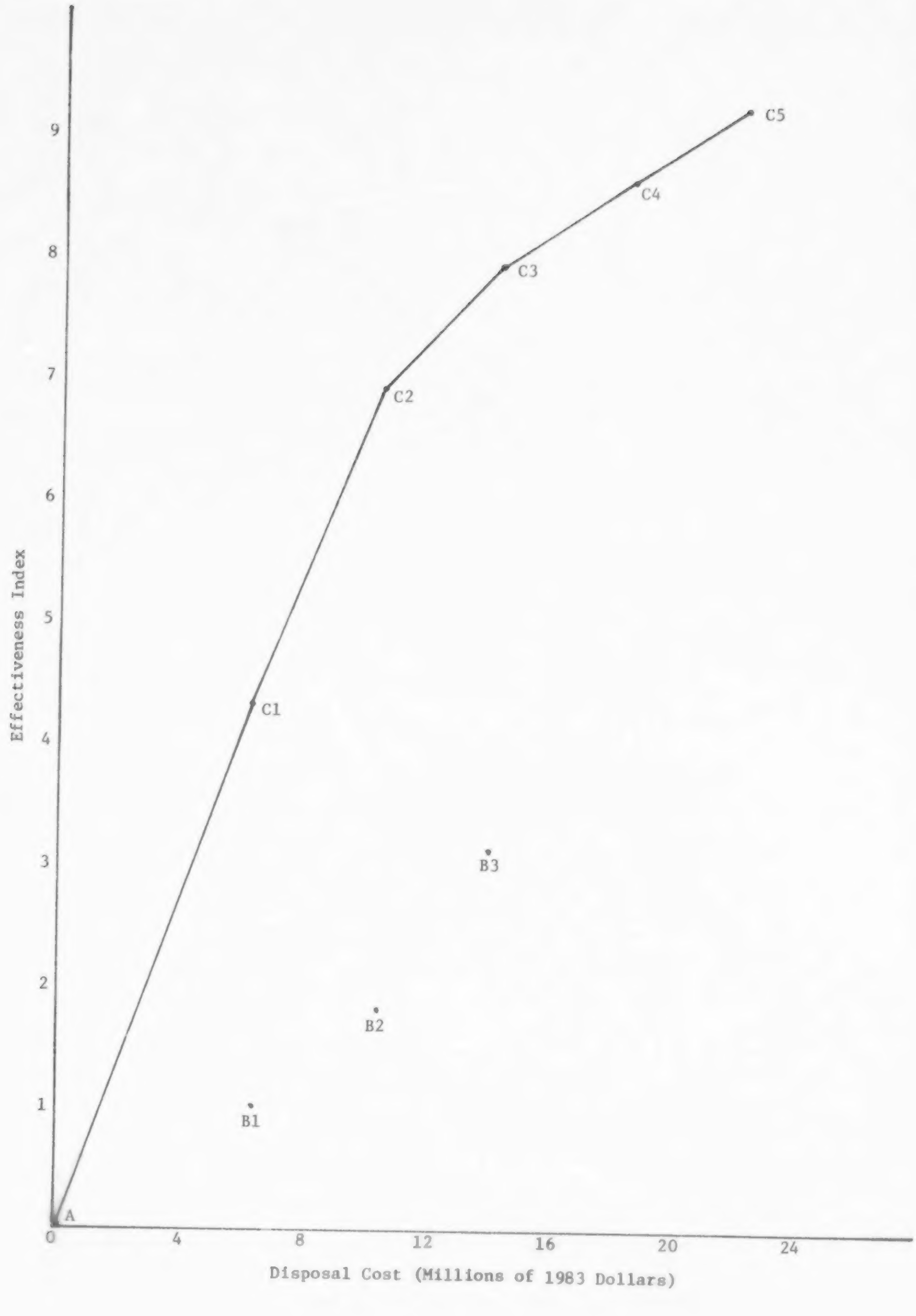

Figure 4.3. Cost-Effectiveness of Control Methods - Existing Tailings, 7 Million MT Pile

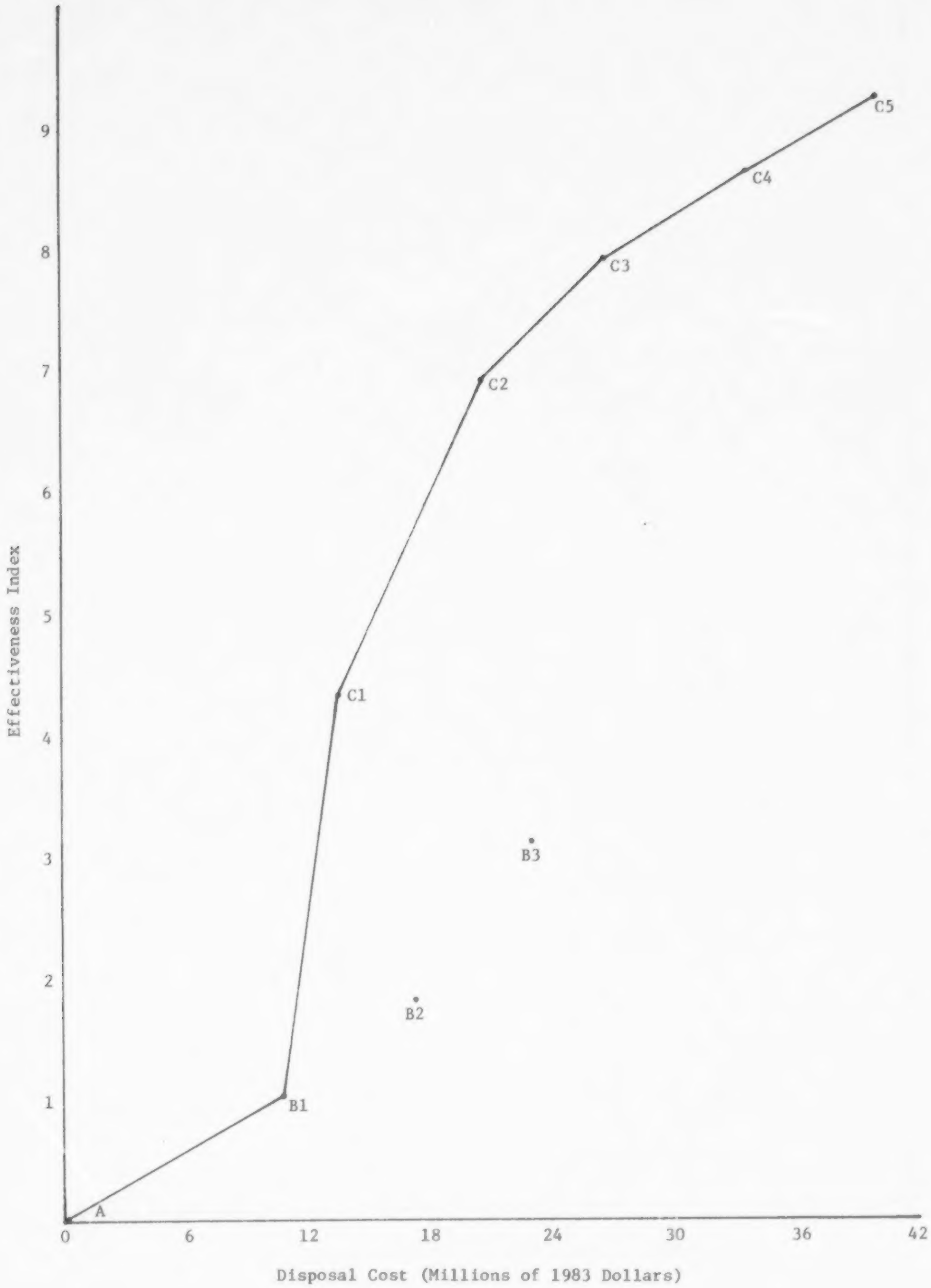

Figure 4.4. Cost-Effectiveness of Control Methods - Existing Tailings, 22 Million MT Pile

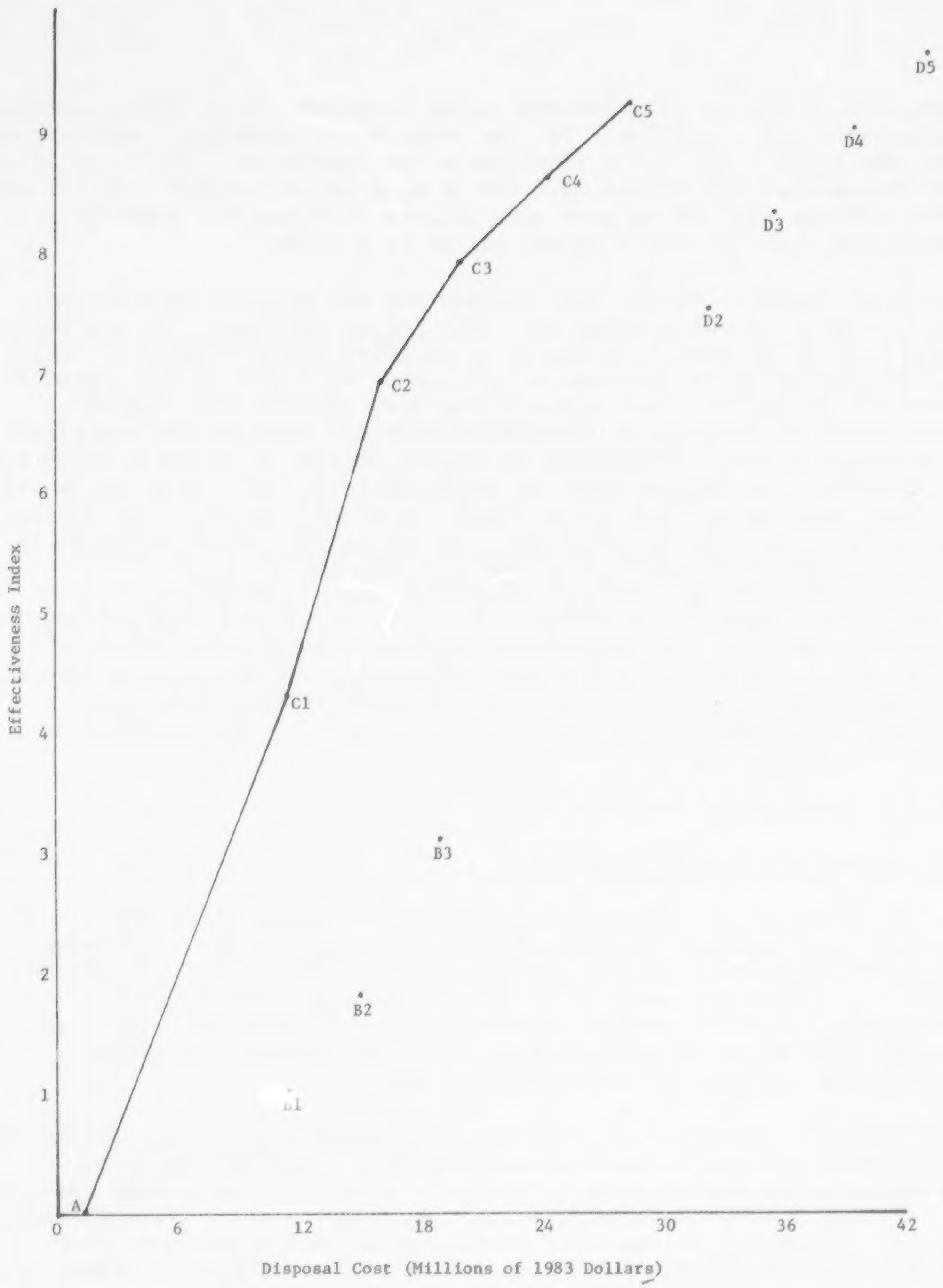

Figure 4.5. Cost-Effectiveness of Control Methods - New Tailings, 8.4 Million MT Pile

points out at what level additional gains in effectiveness start becoming increasingly more expensive. For the other model piles (both existing and new), the results are nearly identical - low incremental cost up to C2 and high incremental cost beyond C2. The changes in incremental cost for each model tailings pile can be seen more clearly in Figure 4.6 where the incremental cost for each disposal method is plotted.

This analysis, though, does not address the disposal methods that existing mills should consider for their future tailings. The regulatory requirement which determines how existing mills should dispose of their future tailings is the groundwater protection provision of the proposed operations standards. In Chapter 5, where we estimate the economic consequences of alternative disposal methods for existing and new piles, we address the issue of disposal of future tailings at existing mills from two extremes. On the one hand, we assume that all existing mills can add to their existing tailings piles indefinitely and dispose of the entire pile at one time. On the other hand, we assume that all existing mills must start new piles immediately with installation of liners. The industry-wide costs and economic impacts of each of these cases is estimated in Chapter 5 for alternative levels of control. In reality, the industry response to the groundwater protection requirement of the operations standards, regarding the implications for disposal of future tailings at existing mills, should be somewhere between these two extremes. In Chapter 6, we present the rationale for the groundwater protection requirement.

4.4.3.1 Sensitivity Analysis

Alternative Weighting Factors

As discussed in Section 4.4.2, the effectiveness index, and therefore the cost-effectiveness analysis, depends very heavily on the judgmental weighting factors for each of the classes of control. In this section, we perform a sensitivity analysis of these weighting factors. Two alternative weighting schemes were devised which represent significant diversions from the original scheme. The effectiveness index was recalculated for each of these distributions.

Table 4.9 presents the original set of weighting factors (Scheme A) and the two alternative distributions (Schemes B and C). Relative to Scheme A, Scheme B represents a substantial shift (25 percentage points) in relative importance to water protection from the other three control classes. Scheme C, on the other hand, represents a significant shift (relative to the original weighting factors) to prevention of misuse (20 percentage points) from the other classes. The effectiveness index resulting from these different sets of weights is also shown in Table 4.9.

We performed the same cost-effectiveness analysis with the alternative weighting schemes. The results for the medium-sized model existing pile and model new pile are displayed in Tables 4.10 and 4.11 for Schemes B and C, respectively. These estimates exhibit the same relationship of cost and effectiveness as the original weighting scheme.

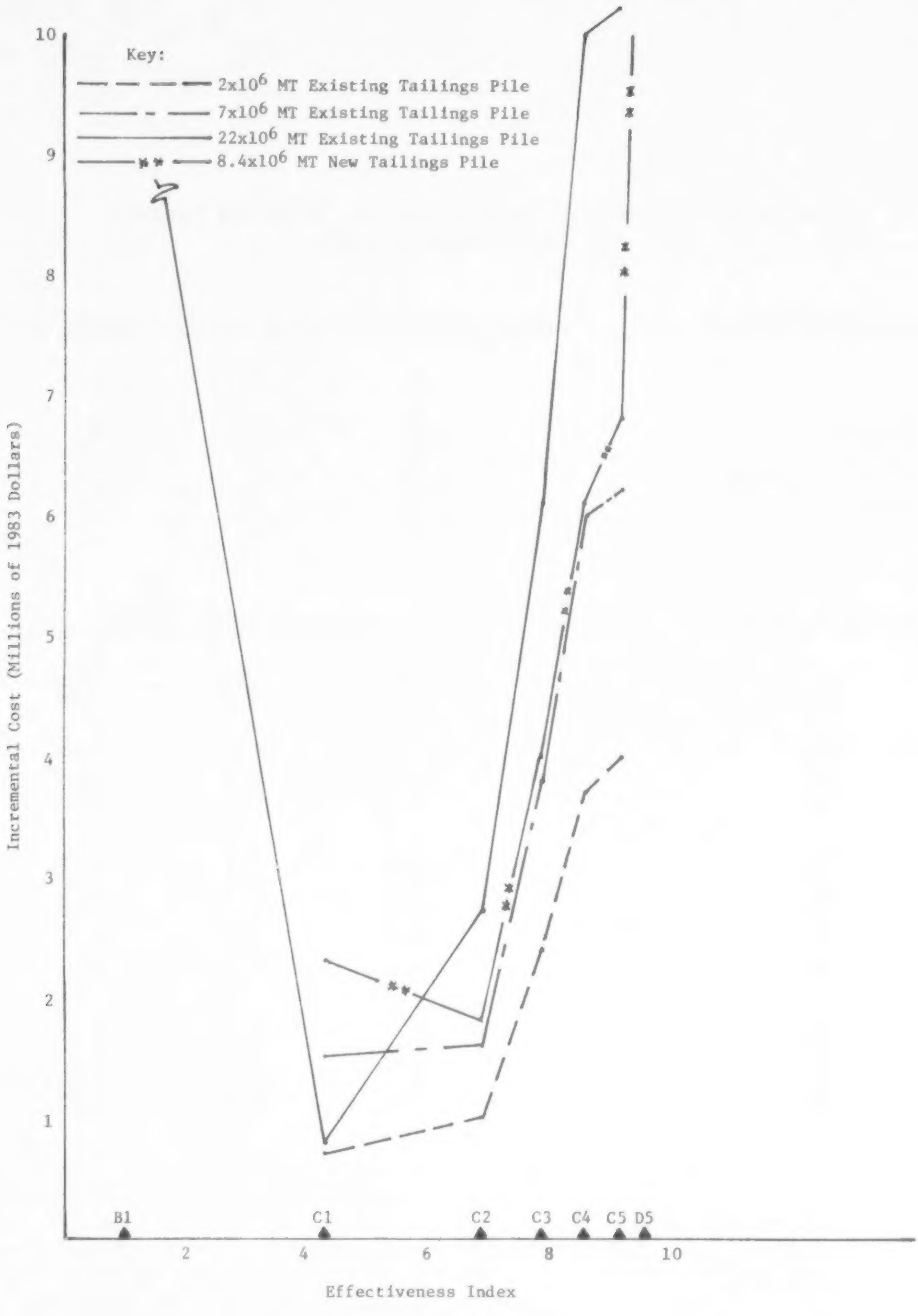

Figure 4.6. Incremental Cost of Alternative Control Methods

Table 4.9. Sensitivity Analysis of Weighting Factors for Effectiveness Index

Classes of Control	Alternative Weighting Factor Schemes (%)		
	A	B	C
Misuse	40	30	60
Radon	30	20	20
Surface Spread	15	10	10
Water	15	40	10

Control Methods	Effectiveness Index		
	A	B	C
A	0.0	0.0	0.0
B1	1.0	1.0	1.0
B2	1.8	1.5	1.5
B3	3.1	2.7	2.7
C1	4.3	3.9	4.2
C2	6.3	6.9	6.6
C3	7.9	7.3	7.6
C4	8.6	7.8	8.4
C5	9.2	8.5	9.1
D2	7.5	6.7	7.3
D3	8.3	7.6	8.2
D4	9.0	8.1	9.0
D5	9.6	8.8	9.7

Table 4.10. Cost-Effectiveness of Control Methods - Alternative Weighting Scheme B

Control Method	Effectiveness Index	Total Cost (10^6 1983 $)	Average Cost	Incremental Cost
7 million MT Existing Pile				
A	0.0	0	---	---
B1	1.0	6.4	Eliminated from consideration	
B2	1.5	10.4	Eliminated from consideration	
B3	2.7	14.0	Eliminated from consideration	
C1	3.9	6.3	1.6	1.6
C2	6.3	10.5	1.7	1.8
C3	7.3	14.3	2.0	3.8
C4	7.8	18.5	2.4	8.4
C5	8.5	22.2	2.6	5.3
8.4 million MT New Pile				
A	0.0	1.3	---	---
B1	1.0	11.4	Eliminated from consideration	
B2	1.5	15.0	Eliminated from consideration	
B3	2.7	19.0	Eliminated from consideration	
C1	3.9	11.4	2.9	2.6
C2	6.3	16.0	2.5	1.9
D2	6.7	32.3	Eliminated from consideration	
C3	7.3	20.0	2.7	4.0
D3	7.6	35.5	Eliminated from consideration	
C4	7.8	24.3	3.1	8.6
D4	8.1	39.5	Eliminated from consideration	
C5	8.5	28.4	3.1	5.6
D5	8.8	43.1	4.9	49.0

Table 4.11. Cost-Effectiveness of Control Methods - Alternative Weighting Scheme C

Control Method	Effectiveness Index	Total Cost $(10^6\ 1983\ \$)$	Average Cost	Incremental Cost
7 million MT Existing Pile				
A	0.0	0	---	---
B1	1.0	6.4	Eliminated from consideration	
B2	1.5	10.4	Eliminated from consideration	
B3	2.7	14.0	Eliminated from consideration	
C1	4.2	6.3	1.5	1.5
C2	6.6	10.5	1.6	1.8
C3	7.6	14.3	1.9	3.8
C4	8.4	18.5	2.2	5.3
C5	9.1	22.2	2.4	5.3
8.4 million MT New Pile				
A	0.0	1.3	---	---
B1	1.0	11.4	Eliminated from consideration	
B2	1.5	15.0	Eliminated from consideration	
B3	2.7	19.0	Eliminated from consideration	
C1	4.2	11.4	2.7	2.4
C2	6.6	16.0	2.4	1.9
D2	7.3	32.3	Eliminated from consideration	
C3	7.6	20.0	2.6	4.0
D3	8.2	35.5	Eliminated from consideration	
C4	8.4	24.3	2.9	5.4
D4	9.0	39.5	Eliminated from consideration	
C5	9.1	28.4	3.1	5.9
D5	9.7	43.1	4.4	24.5

Incremental costs are constant (or even lower) for control method C2, increase by a factor of 2 for method C3, and double again beyond C3. Consequently, we conclude that the level of control determined by the cost-effectiveness analysis is not affected by different weighting factors.

Alternative Time Period of Consideration

Up to this point, we have only been concerned with providing long-term protection from the hazards associated with uranium mill tailings. Long-term, in this sense, is assumed to be about 1000 years. How is this analysis affected if we alter our goal of providing long-term protection and only concern ourselves with protection for a shorter time period? This section presents the cost-effectiveness analysis of the same disposal methods but within the context of protection for a 100-year period rather than the long-term. The methodology is the same, but the effectiveness parameters have necessarily assumed different values.

In Table 4.12, we have reassigned effectiveness ratings for each of the disposal methods to reflect each method's effectiveness in providing the four classes of control for 100 years. In comparison to the 1000-year case (Table 4.7), each disposal option has higher (or in some cases, the same) ratings which shows it is relatively more effective in providing protection for the shorter period than the longer period. The major change from the 1000-year case is in methods B1, B2, and B3, which call for maintenance of the tailings pile for 100 years, the entire duration of the time period now under consideration. While these disposal methods provide little long-term protection, they do provide a substantial amount of protection for 100 years. Although, by definition, the pile is maintained for 100 years, this method does not provide 100 percent protection from misuse since it does not call for continuous policing of the entire tailings pile against intrusion.

Assuming the original benefit weighting factors, we calculate the effectiveness index for each disposal method (see the last column of Table 4.12). We then perform the cost-effectiveness analysis of disposal methods. Table 4.13 shows the results of this analysis for the 7 million MT model existing pile and the model new pile. For each of the model piles, the results indicate that methods C2, C3 and C4 should be eliminated from further consideration since they are dominated by other methods. This analysis shows, therefore, that if we are only concerned with providing protection for 100 years, then the standard should probably reflect active maintenance controls. For the model existing pile, the incremental cost decreases to nearly zero going from method C1 to B1, increases to a level of $2.1 with method B2, then doubles going to B3. Beyond B3 the incremental cost skyrockets. For the model new pile, the incremental cost is reduced by 50 percent going from B1 to B2, then goes back to the B1 value when you reach method B3. Beyond B3, the cost similarly increases substantially. The results of this sensitivity analysis indicate that if controls are only required for 100 years, then the control levels that warrant further consideration are B2 and B3.

Table 4.12 Effectiveness Index for Control Methods by Class of Control, 100-Year Protection Case

Control Method	Prevent Misuse	Radon Control	Prevent Spread of Tailings	Water Protection	Weighted Average[(a)]
A	0	0	0	0	0
B1	8	4	10	4	6.5
B2	9	8	10	6	8.4
B3	9	10	10	7	9.2
C1	5	4	9	4	5.2
C2	7	8	10	6	7.6
C3	9	10	10	7	9.2
C4	9	10	10	7	9.2
C5	9	10	10	8	9.3
D2	8	8	10	6	8.0
D3	10	10	10	7	9.6
D4	10	10	10	7	9.6
D5	9	10	10	8	9.7

(a) The weights for this average are as follows:

I. Prevention of misuse - 40 percent
II. Radon control - 30 percent
III. Prevention of surface spread of tailings - 15 percent
IV. Water protection - 15 percent

Table 4.13. Cost-Effectiveness of Control Methods
100-Year Protection Case

Control Method	Effectiveness Index	Total Cost (10^6 1983 $)	Average Cost	Incremental Cost
7 million MT existing pile				
A	0.0	0	---	---
C1	5.2	6.3	1.2	1.2
B1	6.5	6.4	1.0	0.1
C2	7.6	10.5	Eliminated from consideration	
B2	8.4	10.4	1.2	2.1
B3	9.2	14.0	1.5	4.5
C3	9.2	14.3	Eliminated from consideration	
C4	9.2	18.5	Eliminated from consideration	
C5	9.3	22.2	2.4	82.0
8.4 million MT new pile				
A	0.0	1.3	---	---
C1	5.2	22.9	Eliminated from consideration	
B1	6.5	22.9	3.5	3.3
C2	7.6	27.5	Eliminated from consideration	
D2	8.0	40.4	Eliminated from consideration	
B2	8.4	26.5	3.2	1.9
B3	9.2	30.5	3.3	3.3
C3	9.2	31.5	Eliminated from consideration	
C4	9.2	35.8	Eliminated from consideration	
C5	9.3	39.9	4.3	94.0
D3	9.6	43.6	4.5	12.3
D4	9.6	47.6	Eliminated from consideration	
D5	9.7	51.2	5.3	76.0

REFERENCES FOR CHAPTER 4

ERC83 Energy and Resource Consultants, Inc., "Valuing Reductions in Risk: A Review of the Empirical Estimates," prepared for the U.S. Environmental Protection Agency, February 1983.

NRC80 U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, September 1980.

5. Industry Cost and Economic Impact Analysis

5.1 Industry Cost Analysis

5.1.1 Overview

The purpose of this cost analysis is to estimate the industry-wide cost of mill tailings disposal for alternative combinations of disposal methods which would implicitly be required for compliance with alternative tailings disposal standards. The analysis takes into account the mix of existing tailings, future tailings generated at existing mills, and future tailings generated at new mills. Each combination of disposal methods across these three industry categories is referred to as an economic impact case.

An important limitation of this analysis involves the site-specific nature of mill tailings disposal. There are many parameters which influence the selection of a disposal method and its cost of implementation, the values of which vary from site to site. To accurately estimate the cost of compliance for each economic impact case would require an in-depth engineering study of each site. Instead, we have taken a generic approach in determining likely disposal methods and their costs. We emphasize that the costs of this analysis were developed to achieve consistency among the cases to aid in the selection of proposed standards of general application.

It is important to recognize the differences between these three industry categories. Existing tailings may require different treatments than new tailings to achieve a given level of control. In the case of new tailings (at either an existing or new mill), there is an inherent advantage to integrating tailings disposal with the waste management practices of the mill. The range of controls for existing piles are limited by the realities of the situation, where the quantity, composition, and shape of the pile must be considered in developing remedial action programs. For disposal of future tailings, new mills have an advantage over existing mills since tailings management can be factored into the decision on locating the mill. There are also important differences in the financial considerations faced by existing mills and new mills. Mills with existing tailings have the burden of financing the disposal of existing tailings in addition to financing the disposal of future tailings. Also, existing mills generally have fewer remaining years of plant life over which to finance tailings disposal than new mills. The additional burden of existing tailings disposal cost and the relatively less remaining plant lifetime may result in existing mills experiencing greater economic handicaps than new mills.

5.1.1.1 Formulation of Economic Impact Cases

We developed 25 economic impact cases for the industry cost analysis, each of which corresponds to one of the 13 alternative standards presented in the previous chapter. The concordance of alternative standards, economic impact cases, and control methods by industry category is defined in Table 5.1. We recognize that many other combinations are possible, but we feel that the 25 cases designated for study are viable from a regulatory perspective, provide a sufficient degree of variation, and keep the scope of the analysis manageable in terms of the number of cases to be considered.

The 25 impact cases fall into two general groups according to the treatment of future tailings at existing mills. In one set of cases (1 through 13), this industry category is treated exactly like the existing tailings category and, thus, the same disposal methods are assumed for each. In the other set of cases (26 through 37), future tailings at existing mills are treated the same as future tailings at new mills. Consequently, for these cases we assume that existing mills will separate their future tailings from the tailings which already exist and start new piles. In the first set of cases, this separation of tailings at existing mills is not required.

The cost for a protective liner is included in the disposal cost estimates for new piles for every impact case (except Case 1) even though the liner requirement is not due to the proposed disposal standards, as explained in Chapter 1. We included the liner cost in this analysis in order to estimate the complete economic impact related to mill tailings disposal, regardless of which regulatory provision is responsible for its use.

5.1.1.2 Estimation Methodology

Three types of model entities were used in this analysis. Model existing tailings piles and a model new tailings pile (described in Chapter 4) were developed to estimate the costs of alternative disposal methods. Model uranium mills were developed to analyze the affordability of the tailings disposal costs by the mills. Section 5.1.2.2 presents a summary description of the model mills while an in-depth discussion is found in Appendix A.

For existing tailings, the cost for each disposal method was estimated for three models of existing tailings piles. The estimated cost of disposal for the model existing piles is assumed to apply to each of the piles in that size group. The summation of these costs yields the total cost for disposal of the existing tailings inventory. In light of the aforementioned caveat, we realize that this cost estimation may be inappropriate for representing the disposal cost of a given pile. However, for representing the average cost for a group of similiarly-sized piles, we feel that this methodology is justified in that some sites will undoubtedly cost more while others cost less.

To estimate the cost of disposal for future tailings, we assume that mill operators will set aside funds each year to cover the cost of disposal for the tailings generated in that year. The industry-wide annual cost of disposal is determined by applying an appropriate unit cost of disposal ($/MT of tailings) to the units (MT) of tailings generated in

Table 5.1. Alternative Standards and Control Methods, by Industry Category and Economic Impact Case

Alternative Standard	Economic Impact Case	Existing Mills, Existing Tailings	Existing Mills, Future Tailings	New Mills
A	1	-	-	A-N
B1	2	B1-E	B1-E	B1-N
B1	26	B1-E	B1-N	B1-N
B2	3	B2-E	B2-E	B2-N
B2	27	B2-E	B2-N	B2-N
B3	4	B3-E	B3-E	B3-N
B3	28	B3-E	B3-N	B3-N
C1	5	C1-E	C1-E	C1-N
C1	29	C1-E	C1-N	C1-N
C2	6	C2-E	C2-E	C2-N
C2	30	C2-E	C2-N	C2-N
C3	7	C3-E	C3-E	C3-N
C3	31	C3-E	C3-N	C3-N
C4	8	C4-E	C4-E	C4-N
C4	32	C4-E	C4-N	C4-N
C5	9	C5-E	C5-E	C5-N
C5	33	C5-E	C5-N	C5-N
D2	10	C2-E	C2-E	D2-N
D2	34	C2-E	D2-N	D2-N
D3	11	C3-E	C3-E	D3-N
D3	35	C3-E	D3-N	D3-N
D4	12	C4-E	C4-E	D4-N
D4	36	C4-E	D4-N	D4-N
D5	13	C5-E	C5-E	D5-N
D5	37	C5-E	D5-N	D5-N

that year. Therefore, the cost of disposal for future tailings is assumed to occur at the time the funds are collected and not at the time the disposal activities take place.

We developed a baseline (no EPA standard) projection of uranium industry activities based on the latest DOE Energy Information Administration projections. The industry activities projected include industry demand, annual inventory adjustments, imports, domestic production by conventional mills segmented by existing and new mills, domestic production by nonconventional sources, and the annual average delivered price of U_3O_8. Appendix B explains the development of these projections. The industry demand projection is the same for all economic impact cases. However, we have assumed that the standards may have an impact on the relative shares of future industry production supplied by conventional mills, nonconventional sources, and imports. The projection of annual mill tailings generated at conventional mills, segmented by existing and new mills, is a function of the amount of existing mill capacity projected to operate in the future. To determine projected capacity of existing mills, we have performed a mill closure analysis for each impact case. This analysis investigates the relationship between the disposal cost for mill tailings and the mill operator's decision on whether they can profitably continue production. Since each impact case results in different disposal cost estimates, the mill closure analysis was performed for each case. The analysis was conducted for several model mills and provided an estimate of the existing industry capacity that can be expected to remain in operation. Appendix A presents an in-depth description of the mill closure analysis.

In the baseline case, estimates of conventional mill capacity in operation, on standby due to market conditions, and permanently closed are made on a yearly basis in relation to the industry demand estimated to be supplied by the conventional mill sector. New mill capacity is introduced only after all the capacity on standby has been reopened. Once the schedule of existing and new mill capacity is established, the annual production at each is calculated according to their respective yearly capacities. In cases where regulatory closures occur, additional (above the baseline case) standby capacity is reopened to avoid any shortfall in conventional mill production. However, if the number of regulatory closures is greater than the standby capacity, then a shortfall in conventional mill production takes place. This shortfall is assumed to be met by either additional imports or nonconventional production, either of which would not result in additional mill tailings being generated. Additional (above the baseline case) new mill capacity is assumed not to be added in response to regulatory closures through the year 1989. However, after 1989, if a shortfall in conventional mill production still exists, then new mill capacity is assumed to be added. This constraint on new mill capacity from 1983-1989 recognizes that it takes a certain amount of lead time before a new mill can become operational. Appendix B explains this methodology in much more detail and presents the annual projections of industry production for each impact case, segmented by existing and new mills.

For future tailings at new mills, the unit cost of disposal ($/MT of tailings) from the model new pile cost analysis is applied to the annual projections of industry production at new mills to derive the annual industry cost of disposal.

The unit cost of disposal of future tailings at existing mills is derived from both the cost estimations for the three model existing piles and the model new pile, depending on the individual impact case. If the case allows existing mills to add future tailings to their existing piles (Cases 1 through 13), then the unit cost of disposal for the future tailings is assumed to equal the incremental unit cost of disposal estimated from the costs of the three model existing piles. If the case requires existing mills to start new piles for future tailings (Cases 26 through 37), then the unit cost of disposal for existing mills, future tailings, assumed the same value as that derived for the model new pile.

Once the projections of industry production and the estimations of unit costs by category have been made, then the calculation of the aggregate cost of compliance to the uranium milling industry can be performed. As stated earlier, applying the unit cost of disposal to the quantity of tailings generated each year provides an estimate of the annual cost of disposal for future tailings, derived separately for existing mills and new mills. Since the existing tailings inventory has been estimated as of the end of 1982, future tailings are defined as the tailings generated from 1983 through the year 2000.

For existing tailings, we assumed that the entire industry disposal cost will be incurred over the five-year period, 1983 through 1987. We allocated the total cost in equal amounts to each of the five years. This does not mean that disposal activities will necessarily take place during this time frame, but rather that this is the time over which we assumed the money to pay for the disposal will be raised.

These calculations result in the development of three categories of yearly flows of disposal costs from 1983 to 2000: existing mill tailings, future tailings generated at existing mills, and future tailings generated at new mills. The yearly flows of industry costs are presented for each impact case in Appendix C. A present worth analysis of the costs was also performed for each case. The present worth estimates were calculated for three alternative discount rates: 10, 5, and 0 percent.

5.1.2 Cost Estimation

Following the procedure explained above, we have estimated the industry-wide cost of each impact case for each industry category. The sum of the costs for the three industry categories represents the total cost for the case. The total cost is expressed in several ways according to different scenarios for the discount rate.

5.1.2.1 Existing Tailings

Table 5.2 presents the total disposal cost for the 26 existing tailings piles. These costs were derived by multiplying the appropriate model pile cost (from Chapter 4) by the number of piles in that model-size category. Alternative standards C and D result in the same costs since the standards require the same controls on existing piles. One observation from these cost estimates is that alternatives C1, C2, and C3 cost approximately the same in the aggregate as alternatives B1, B2, and B3, even though different control methods were assumed for each. As stated above, we assume that the costs are to be funded in five equal increments over the period 1983 to 1987.

5.1.2.2 Future Tailings

For future tailings at both existing and new mills, the annual industry disposal cost was derived by multiplying the appropriate unit cost of disposal by the industry production projected for each year. Table 5.3 presents for each impact case the industry unit cost of disposal for existing and new mills. These costs are expressed on the basis of dollars per metric ton of U_3O_8 (converted from unit costs on a tailings basis) and are applied to the industry U_3O_8 production estimates presented in Appendix B.

For Cases 2 through 13, the industry unit cost for existing mills is a weighted average of the incremental unit costs for the three model existing tailings piles estimated for each control method. The incremental unit cost for each model existing pile was derived by estimating the additional cost of adding one million MT of tailings to each of the piles. This additional cost was estimated by first calculating the total disposal cost for each control method for a 3, 8, and 23 million MT pile and then subtracting from these estimates the model pile costs presented in Chapter 4 for a 2, 7, and 22 million MT pile. This difference in cost, divided by one million tons, yields the incremental unit cost for each control method. The same surface area of the three model tailings impoundments was used for these calculations since it was assumed that tailings could only be added to existing piles in a vertical manner without requiring compliance with the primary groundwater protection standard, that is, placing a liner beneath the tailings. Horizontal expansion of existing piles would require liners, the cost of which should approximate the cost for starting new piles, which was estimated for each alternative disposal standard in Cases 26 through 37. Table 5.4 shows the total cost estimates for the 3, 8, and 23 million MT piles for each economic impact case where tailings are adding to existing impoundments. The table also shows the incremental unit cost for each model pile size, as well as the weighted average incremental unit cost. The weights used were 35 percent for the 2 million MT pile, 45 percent for the 7 million MT pile, and 20 percent for the 22 million MT pile. These weights represent an estimate of the relative shares of future tailings at each of the existing pile size categories, calculated according to the generalized matrix of the 24 existing mills presented in Table A.1.

Table 5.2. Total Disposal Cost for Existing Tailings (26 Piles), By Alternative Standard and Economic Impact Case (Millions of 1983 Dollars)

Alternative Standard	Economic Impact Case	Pile Size: (10^6 MT)	2	7	22	Total Cost
		# of Piles:	11	12	3	
A	1		-	-	-	-
B1	2, 26		46	77	32	155
B2	3, 27		76	125	52	253
B3	4, 28		101	168	69	338
C1	5, 29		35	76	41	152
C2	6, 30		65	126	62	253
C3	7, 31		91	172	80	343
C4	8, 32		120	222	101	443
C5	9, 33		146	266	120	532
D2	10, 34		65	126	62	253
D3	11, 35		91	172	80	343
D4	12, 36		120	222	101	443
D5	13, 37		146	266	120	532

Table 5.3. Industry Unit Costs for Disposal of Future Tailings (1983 dollars)

Alternative Standard	Economic Impact Case	Existing Mills ($/MT Tailings)	Existing Mills ($/MT U_3O_8)	New Mills ($/MT Tailings)	New Mills ($/MT U_3O_8)
A	1	--	--	0.15	--
B1	2	0.09	97	2.73	2935
B1	26	2.73	2935	2.73	2935
B2	3	0.12	129	3.15	3386
B2	27	3.15	3386	3.15	3386
B3	4	0.15	161	3.63	3902
B3	28	3.63	3902	3.63	3902
C1	5	0.37	398	2.73	2935
C1	29	2.73	2935	2.73	2935
C2	6	0.42	452	3.27	3515
C2	30	3.27	3515	3.27	3515
C3	7	0.47	505	3.75	4031
C3	31	3.75	4031	3.75	4031
C4	8	0.52	559	4.26	4580
C4	32	4.26	4580	4.26	4580
C5	9	0.57	613	4.75	5106
C5	33	4.75	5106	4.75	5106
D2	10	0.42	452	4.81	5171
D2	34	4.81	5171	4.81	5171
D3	11	0.47	505	5.19	5579
D3	35	5.19	5579	5.19	5579
D4	12	0.52	559	5.67	6096
D4	36	5.67	6096	5.67	6096
D5	13	0.57	613	6.10	6558
D5	37	6.10	6558	6.10	6558

Table 5.4. Derivation of Incremental Unit Cost of Adding Tailings to Existing Impoundments

Economic Impact Case	Total Disposal Cost (10^6 1983 $)			Incremental Unit Cost (1983 $/MT Tailings)			
	3 million MT	8 million MT	23 million MT	2 million MT	7 million MT	22 million MT	Weighted Average[(a)]
2	4.32	6.51	10.92	.09	.09	.11	.09
3	7.00	10.56	17.40	.12	.13	.12	.12
4	9.40	14.13	23.15	.16	.15	.11	.15
5	3.64	6.70	13.73	.47	.39	.17	.37
6, 10	6.41	10.96	20.72	.54	.44	.17	.42
7, 11	8.87	14.74	26.97	.60	.49	.18	.47
8, 12	11.60	18.98	33.97	.68	.53	.22	.52
9, 13	14.03	22.78	40.20	.75	.59	.22	.57

(a) The weights used for this average were 35 percent for the 2 million MT pile, 45 percent for the 7 million MT pile, and 20 percent for the 22 million MT pile.

For Cases 26 through 37, the industry unit cost for existing mills is the same as the industry unit cost for new mills since these cases assume that future tailings at existing mills will be disposed in the same manner as future tailings at new mills. The industry unit cost for new mills in Table 5.3 is the appropriate unit cost for the model new pile (from Chapter 4). The average unit cost for the model new pile may understate the actual disposal cost for future tailings for those mills whose future generation is less than that assumed for the model new pile (8.4 million MT). The understatement of cost will occur if the economy of scale relationship that we observe for the existing tailings piles is applicable to new piles. Since we have assumed one model new pile size, we have only one data point and, therefore, cannot accurately test for scale economies. Nevertheless, for representing an industry average unit disposal cost, the model new pile cost appears reasonable since some existing mills will generate more than 8.4 million MT of tailings and, therefore, partially offset the diseconomy of scale from the mills with limited future production.

Mill Closure Analysis

We performed a mill closure analysis for each economic impact case for two purposes. First, we need to examine the economic impact of the alternative standards on an individual facility basis to determine the distributional effects. Section 5.2, Economic Impact Analysis, analyzes this issue. Second, we need to know if the standard will cause any shifts in how the industry demand will be supplied. Specifically, we need to know if there will be an effect on the amount of uranium produced at conventional mills since this determines the quantity of future mill tailings that need to be disposed. Also, industry production at existing mills versus new mills may differ by impact case according to the results of the mill closure analysis. Consequently, the industry cost estimates may be affected by the results of mill closure analysis.

The mill closure analysis is based on the use of a discounted cash flow (DCF) technique which indicates whether or not a project is justified on economic grounds. The DCF analysis compares, on a model mill basis, the discounted cost of disposal for each case to the discounted cash flow over the life of the project. We assume that the entire cost of disposal for both existing and future tailings is absorbed by the mill with no price pass-through. Considering the disposal costs for both existing and future tailings may overstate the financial impact if one assumes that the mills have already assumed the liability for the disposal of existing tailings. This latter situation appears to be the case since, as part of the mill's licensing requirements, they must develop a tailings disposal plan with cost estimates and arrange a financial assurance mechanism which will cover the cost of disposing of the tailings. However, the tailings disposal plan developed for licensing may not be in compliance with the EPA standard. Therefore, the costs for disposal may be higher than the cost estimates made for licensing. For purposes of estimating the impact on future industry production, we have included the cost of both existing and future tailings in the mill closure calculation. In the economic impact section, we discuss the effect of only considering future tailings on mill closures.

The cash flow (pre-tax) for this analysis is defined to be 20 percent of revenues (15 percent operating profit plus 5 percent depreciation and depletion). If the discounted cash flow is greater than the discounted cost of disposal, then we conclude that the model mill will continue operation. If the reverse is true, then the mill closes. The effects of varying the cash flow and cost absorption assumptions on the mill closure analysis are discussed in the sensitivity analysis section of Appendix A.

For the mill closure analysis, model mills are distinguished by three parameters: capacity of the mill, remaining operating life of the mill, and the size of existing tailings pile. Three mill capacities (900, 1800, and 3600 MT ore per day), three operating lives (5, 10 and 15 years), and three sizes of existing piles (2, 7, and 22 million MT) are assumed. These assumptions result in 27 (3x3x3) possible model mills for the analysis. After examining the characteristics of the licensed uranium mills, we have placed each of them in one of 16 model mill categories. A separate analysis was performed for each of the 16 model mills and for each impact case. Table 5.5 summarizes the results of the mill closure analysis, while Appendix A presents a detailed description of the methodology and results of the analysis.

Projections of Industry Production and Disposal Costs

Based on the DOE/EIA projection of industry demand and several computer runs from DOE's uranium industry model (EUREKA), we have estimated, year-by-year, the industry uranium production by conventional mills. This projection, made on an annual basis from 1983 through 2000, is shown in Table 5.6, accompanied by a projection of delivered uranium prices. The methodology, which is explained in depth in Appendix B, considers the following: reduction of inventories, penetration by imports, domestic production by nonconventional sources, the obsolescence of existing capacity (permanently retired due to economic reasons), the industry's annual average capacity utilization rate, premature mill closings (temporary reductions in capacity due to market conditions), reopening of mills from standby, and the introduction of new mill capacity. Based on the new and existing mill capacities and the industry average capacity utilization rate, annual industry production is calculated for both new and existing mills. Upon considering the mill closures (Table 5.5) due to the disposal costs for each case, additional closures may result which, in order to meet the industry demand, forces changes in the baseline projection of mills reopening from standby, the addition of new mill capacity, and the schedule of imports and nonconventional production. Separate tables for each impact case (or group of cases resulting in the same number of mill closures) showing the yearly changes to each of these parameters are also presented in Appendix B.

Table 5.5. Summary of Mill Closure Analysis[a]

Economic Impact Case	Model Mill Closures
1-8, 10-12, 26-31, 34	No Closures
9, 13, 32, 33, 35, 36	1 small mill
37	2 small mills

[a] Based on assumptions of 100 percent cost absorption, 20 percent cash flow margin, and includes the disposal costs for both existing and future tailings.

Table 5.6. Baseline Projection of Industry Demand, Production by Conventional Mills, and Delivered Uranium Price, 1983-2000

Year	Industry Demand 10^3 MT U_3O_8	Conventional Production 10^3 MT U_3O_8	Average Delivered Price (1983 $ per pound of U_3O_8)
1983	12.7	7.5	29.10
1984	15.9	6.3	36.59
1985	17.1	7.3	42.54
1986	17.7	7.8	68.47
1987	16.3	6.7	82.87
1988	20.0	7.4	92.99
1989	17.7	7.6	92.09
1990	18.1	9.5	87.84
1991	18.4	9.2	81.93
1992	18.3	10.2	74.66
1993	19.0	10.3	75.24
1994	19.7	10.0	77.06
1995	20.4	10.5	79.14
1996	20.7	10.0	80.39
1997	21.3	9.3	93.32
1998	23.0	9.7	89.26
1999	25.1	10.2	83.86
2000	26.9	11.3	79.91

Source: Appendix B.

By applying the industry unit disposal costs (Table 5.3) to the estimates of production at new and existing mills (Appendix B tables) we derive the annual disposal cost for future tailings at new and existing mills. Appendix C presents the yearly flows of these disposal costs, along with the existing tailings disposal costs, for each impact case. The cumulative costs for each economic impact case are presented in Table 5.7.

As Table 5.7 shows, we have made two cost estimates for each alternative standard. They differ in that the first case assumes that all future tailings at existing mills are added to existing impoundments, while the second case assumes all future tailings at existing mills are placed in new impoundments. Therefore, we have estimated two possible outcomes of the same disposal standard. As explained in earlier chapters, different outcomes of the same disposal standard are possible because of the groundwater protection standard during operations. When viewed from the aggregate industry level, the two outcomes estimated in this analysis are extremes, with the likely outcome falling somewhere between these extremes.

To determine where between these extremes the most likely outcome would take place, we would need to know, on an individual site basis, several things. Regarding tailings management, we need to know the remaining capacity of existing impoundments, whether or not the groundwater is contaminated, and, if so, whether or not a corrective action program can be implemented which would allow additional tailings to be added to the existing impoundments. Compliance with the groundwater protection requirements and the development of corrective action programs involve determinations to be made by the regulatory agencies after the situation has been monitored. Also, some of the mills currently on standby may have to dispose of the existing tailings if the mill remains closed for an extended period and put the tailings from any future production in new impoundments. Clearly, this information is not currently available. Even if it were, however, we would then need to make a projection on the future uranium production and tailings generation for each existing mill and any new mills which may be started in the future. While we feel we can make a reasonable projection of overall industry activity, we are in no position to distribute this projection over individual facilities.

NRC has estimated that, for their licensed mills in Utah and Wyoming, about 75 million MT of tailings capacity is remaining. We, thus, believe that at least 125 million MT of remaining tailings capacity is available at existing mills industry-wide. In our baseline projection, we estimate that about 150 million MT of tailings will be generated at existing mills out of a total of 175 million MT of future tailings. However, assuming, like we do in impact cases 1 through 13, that all future tailings at existing mills are placed in existing impoundments may not be likely from a tailings management perspective even if the existing impoundments can be modified to accommodate all 150 million tons. This is because our

Table 5.7. Cumulative Industry Disposal Costs, 1983-2000
(millions of 1983 dollars)

Alternative Standard	Economic Impact Case	Industry Costs, Undiscounted			Present Worth Costs (10% discount rate)
		Existing Tailings	Future Tailings	Total	
A	1	0	4	4	1
B1	2	155	84	239	141
B1	26	155	474	629	319
B2	3	253	98	351	219
B2	27	253	549	802	424
B3	4	338	114	452	288
B3	28	338	632	970	524
C1	5	152	124	276	157
C1	29	152	474	626	316
C2	6	253	145	398	240
C2	30	253	570	823	433
C3	7	343	165	508	314
C3	31	343	653	996	537
C4	8	443	186	629	397
C4	32	443	744	1187	651
C5	9	532	215	747	474
C5	33	532	829	1361	755
D2	10	253	184	437	249
D2	34	253	837	1090	546
D3	11	343	201	544	323
D3	35	343	906	1249	644
D4	12	443	221	664	406
D4	36	443	989	1432	755
D5	13	532	252	784	483
D5	37	532	1065	1597	855

projection of conventional production is sufficiently low so that the last increment of standby capacity is not reopened until 1991. It is highly unlikely that a mill currently closed and reopening eight years later (perhaps under a different operator) will be allowed to add tailings to the impoundment existing today. Consequently, even before considering the impact of compliance with groundwater protection requirements, the amount of future tailings at existing mills that are placed in existing impoundments should be less than 100 percent. Regarding groundwater protection, we noted in Chapter 3 that two mills have already constructed new lined ponds to alleviate groundwater contamination. As stated above, we do not know at this time how typical an outcome this will become. For purposes of estimating the most likely cost associated with each alternative standard, we have assumed that two-thirds of the future tailings at existing mills will be placed in existing impoundments and one-third in new impoundments. This assumption applies uniformly to each alternative standard. Table 5.8 presents the results of this calculation for all the alternative standards.

5.2 Economic Impact Analysis

5.2.1 Introduction

The purpose of this section is to present an analysis of the economic impacts associated with the costs of the various cases. The intent is to present the methodology for estimating the impacts and the range of results for all cases. In Chapter 6, we summarize the economic impacts associated with the proposed standards. For discussion purposes, the economic impacts are presented at three separate levels: the uranium industry level, the regional level, and the macroeconomic level. Although the three levels are presented separately, they are closely interrelated.

There is a significant amount of uncertainty in predicting the future course of the uranium industry. The initial source of the uncertainty is the schedule of installed reactor capacity from which the demand for uranium can be derived. The conditions surrounding this uncertain forecast were discussed in Chapter 2. Given a reliable uranium demand scenario, though, it is still highly uncertain how this demand will be met. Due to lower cost foreign uranium deposits and public utility commission objectives on the one hand, and potential import restrictions and utilities' "Buy American" policies on the other hand, we cannot accurately determine how much of this demand will be provided by foreign sources versus domestic sources (see Chapter 2). Regarding domestic production, we do not know for certain how long existing mills will continue to remain in operation. Mills have closed for a variety of reasons, including exhaustion of economically-produced ore deposits, financial problems, and a pessimistic long-run outlook on the uranium industry by the parent corporation compared to other business ventures. If we had information on each mill's existing contracts, we might be in a better position to estimate their remaining lifetimes. However, even this

Table 5.8. Total Cost of Alternative Standards
(millions of 1983 dollars)

Alternative Standard	Total Cost, Undiscounted	Present Worth Cost (10% discount rate)
A	4	1
B1	369	200
B2	501	287
B3	624	367
C1	393	210
C2	540	304
C3	671	388
C4	815	482
C5	951	568
D2	654	348
D3	779	430
D4	920	522
D5	1055	607

information would not be conclusive since some mills with long-term contracts have still shut down and are honoring their contracts by making purchases on the spot market from buyers with excess supply. These uncertainties also prevent us from making an accurate projection of uranium prices.

The Department of Energy, Energy Information Administration, is the best source of information within the Federal Government about the future of the uranium industry. By the use of surveys and quantitative models, they have made several forecasts of uranium industry activities according to various scenarios. Based on information obtained from DOE/EIA which was expressly prepared for this EPA study (see Appendix B), we developed a projection of the industry which takes into account the working down of existing excess inventories, imports, retirements of capacity due to exhaustion of ore deposits, variable capacity utilization rates, premature closings due to market conditions, and additions of new capacity. Industry average delivered uranium prices were also projected. These projections of uranium industry activity are necessary so that we can measure the economic impacts of the alternative standards. The impacts estimated in this chapter are intended to show the incremental effects of tailings disposal and are not intended to be a prediction on what we think the future of the industry will be like. Based on all these uncertainties, we do not feel that accurate long-run predictions of the uranium industry can be made.

5.2.2 Uranium Industry Impacts

5.2.2.1 Production Cost Increases and Potential Price Effects

One method of estimating the economic impact at the uranium industry level is to examine the percentage increase in production cost represented by the additional costs of tailings disposal. This cost increase would vary by individual mill since the production capacity, remaining lifetime, and size of existing tailings pile each affect the amount of the disposal cost. On a relative basis, the larger cost increases would result in those cases represented by small capacity, few years of remaining lifetime, and large quantities of existing tailings. Table 5.9 shows the range in percentage production cost increases across the model mills for each impact case, assuming a base production cost (excluding profit) of \$30 per pound of U_3O_8. Cost increases for the least impacted model existing mill vary across impact cases from 0.7 to 11.8 percent. The cost increase for the most impacted existing mill varies from 10.4 to 45.8 percent. Alternatively, the estimates of cost increases were arranged to show the range across all cases for each model existing mill, as presented in Table 5.10. The percentage cost increase is estimated to range from 2.2 percent to 45.8 percent for a small model mill. For a medium-sized model mill, the percentage cost increase ranges from 1.2 percent to 18.4 percent. For a large model mill, the percentage cost increase ranges from 0.7 percent to 26.2 percent. For a model new mill, the percentage cost increase ranges from 0.3 percent to 10.2 percent. Appendix A (Tables A-9, A-10, A-11c, and A-12) shows the complete results for all model mills.

Table 5.9. Range of Production Cost Increases across Model Mills by Economic Impact Case[a] (percents)

		Existing Mills		New Mills
Alternative Standard	Economic Impact Case	Model with Lowest Production Cost Increase	Model with Highest Production Cost Increase	Production Cost Increase
A	1	0.0	0.0	0.3
B1	2	0.7	10.4	4.5
B1	26	5.0	14.8	4.5
B2	3	1.0	16.9	5.3
B2	27	6.1	21.9	5.3
B3	4	1.4	22.7	6.1
B3	28	7.2	28.5	6.1
C1	5	1.2	10.8	4.5
C1	29	4.9	14.6	4.5
C2	6	1.6	17.6	5.5
C2	30	6.2	22.3	5.5
C3	7	2.0	23.7	6.2
C3	31	7.2	29.2	6.2
C4	8	2.4	30.5	7.1
C4	32	8.4	36.8	7.1
C5	9	2.8	36.6	7.9
C5	33	9.5	43.5	7.9
D2	10	1.6	17.6	8.0
D2	34	8.7	24.9	8.0
D3	11	2.0	23.7	8.7
D3	35	9.6	31.6	8.7
D4	12	2.4	30.5	9.4
D4	36	10.7	39.1	9.4
D5	13	2.8	36.6	10.2
D5	37	11.8	45.8	10.2

[a] Assumes a base production cost (excluding profit) of \$30 per pound of U_3O_8.

Table 5.10. Range of Production Cost Increases across Economic Impact Cases by Model Existing Mill[a] (percents)

	Size of Existing Tailings Pile								
	2 million MT			7 million MT			20 million MT		
	5 yrs	10 yrs	15 yrs	5 yrs	10 yrs	15 yrs	5 yrs	10 yrs	15 yrs
Small Mill									
Low	5.9	3.2	2.2	10.4	4.9	NA	NA	NA	NA
High	31.5	20.0	16.5	45.8	26.6	NA	NA	NA	NA
Medium Mill									
Low	NA	1.7	1.2	NA	2.5	1.7	NA	NA	NA
High	NA	15.1	13.3	NA	18.4	15.5	NA	NA	NA
Large Mill									
Low	NA	NA	0.7	2.7	1.3	0.9	4.5	2.2	1.5
High	NA	NA	11.8	19.1	14.3	12.8	26.2	17.6	14.9

[a] Assumes a base production cost of \$30 per pound of U_3O_8.

NA = Not Applicable.

For some cases and model mills, the production cost increases are quite large. In light of the depressed condition of the uranium industry and the threat from foreign competition, it is highly unlikely that all of the costs of tailings disposal can be passed on to customers. However, it is possible that part of the control costs could be passed-through in the form of higher prices since: (1) all of the existing mills and new mills are subject to control costs (although control costs may vary across the industry, the industry as a whole should pass-through at least a part of the control costs), (2) as discussed in Chapter 2, the demand for uranium is inelastic with respect to price, and (3) a substantial part of U_3O_8 production is purchased under long-term contracts which have cost escalation clauses, including cost increases due to regulations.

The model existing mill with the lowest cost increase for each case is a large mill with 15 years remaining lifetime and a small existing tailings pile. This model mill may be viewed as the industry price leader, in that existing mills will probably be unable to raise their prices above those of the least impacted mill and remain competitive. Alternatively, the cost increase for a new mill may also constrain the amount of the disposal cost that can be passed on to customers by existing mills since new mills will only be constructed and operated if they can cover all the costs of production. Therefore, we feel that the most likely potential price increase taking place as a result of tailings disposal will fall within the range of the production cost increases estimated for the least impacted model existing mill and the model new mill. This most likely price increase range is indicated for each impact case from the production cost estimates in Table 5.9.

In cases where there are large increases in production costs, the competitiveness of the domestic industry with respect to foreign industry could be reduced and thereby lead to increased imports. Also, in the case of significant differential cost increases for small mills, this could lead to shifts in the size distribution of the industry away from smaller mills toward larger mills.

5.2.2.2 Mill Closures

For those cases where the production cost increases are substantial, part or all of the disposal costs may have to be absorbed by the mills. This could lead to closures of some mills. Assuming the conditions of a medium cash flow margin (20 percent) and no pass-through of the control costs, the number of mill closures may range from zero to two small model mills for Case 37 (see Table 5.5). Appendix A presents the complete mill closure results and includes variations in the cash flow margin and price pass-through assumptions.

In addition to the no pass-through scenario, we have analyzed the effects of two different levels of price pass-through on the mill closure analysis, a one dollar and a two dollar per pound increase in the price of U_3O_8. These limited pass-throughs of the disposal cost represent increases of 3.3 to 6.6 percent, assuming a base yellowcake price of $30 per pound. These price increases approximate the range in the production cost increases estimated for the least impacted model existing mill and the model new mill, as shown in Table 5.9. Therefore, these pass-through levels are reasonable representations of the average industry response to the requirements of the impact cases.

For the six cases which result in one small model mill closure under conditions of no pass-through and a 20 percent cash flow margin, a $1 per pound pass-through will eliminate the closure for one of the cases, while the $2 per pound pass-through will eliminate the closure for three more cases. For Case 37, the two small mill closures under no pass-through and a 20 percent cash flow margin are reduced to one closure with either a $1 or $2 per pound pass-through.

As discussed earlier in this chapter, mills must develop tailings disposal plans as part of their licensing requirements. They must also implement a financial assurance mechanism whereby funds will be available for tailings disposal in the event that a mill closes prematurely. One can reasonably assume, then, that the mills have already assumed the financial liability for the tailings which have accumulated to date. The costs for existing tailings can be viewed as a fixed cost of production, to be paid regardless of whether a mill continues operating or not. The decision to continue operating in the future may, therefore, be based on the incremental cost of disposal of future tailings only. If a mill's future cash flow can cover the variable cost of production, including the incremental cost of future tailings disposal, then we would expect the mill to continue operating or at least not close for tailings-related reasons. We alternatively performed the mill closure analysis by zeroing out the cost for existing tailings and only including the cost of future tailings in the closure calculation. The results of this estimation indicate that none of the model mills would close. Further discussion of the mill closure issue is presented in Chapter 6 where the economic impact of the standard is described.

5.2.2.3 Methods of Raising Capital

In some cases the disposal costs involve considerable sums of money. This may require firms in the industry to raise additional capital in order to meet these costs. Most of the firms in the industry are large corporations that will have access to a wide variety of financing alternatives and capital markets. Raising capital for pollution control expenditures is similar to raising capital for other expenditure programs; therefore, standard procedures for raising capital are applicable. Examples are the sale of common stock, corporate bonds, and commercial paper, or the firm can seek commercial bank loans. In some cases, the firms may be able to finance control expenditures with retained earnings.

5.2.2.4 Ability to Raise Capital

The ability to raise capital is dependent upon a firm's current and projected financial condition. If a firm is considering an investment that is projected to be profitable and it has a good credit rating based on past performance, capital generally will be available. Undoubtedly, some firms will find it easier to raise capital than will others. If an investment is not projected to be profitable, then there is no economic incentive to raise capital, even though the firm may have the ability to do so.

The financial condition of a firm can be assessed through a combination of factors. They include sales, profitability, liquidity, and leverage. Table 5.11 shows the sales for most of the existing firms in the industry. Sales are shown for the total company and the business segment within the company that includes the milling of uranium. The percentage of the company's total sales provided by the uranium milling segment is also shown. In some cases the uranium milling segment may also include other products. A company's total sales is one indicator of a company's ability to raise capital because larger companies are likely to have access to a broader range of methods to raise capital than smaller companies. The dollar volume of sales by the segment that includes uranium milling, together with the percentage of the company's total sales that are provided by this segment, are additional indicators of a firm's ability to raise capital. For example, if the uranium market is depressed and a firm depends on uranium milling for a high proportion of its business, then such a firm is more likely to experience difficulty in raising capital than another firm that is less dependent on uranium milling. In approximate terms, Table 5.11 suggests that, based on sales, there are two groups in the industry. One group has sales that are many billions of dollars, with a small percentage of those sales provided by uranium milling. The second group has sales that are considerably less than the first group and are relatively more dependent on uranium milling.

Another important measure of a firm's ability to raise capital is its debt in relation to its total capitalization, which is called leverage. If a firm has a high percentage of debt to total capitalization, then the firm has little leverage and is probably less able to raise new capital than is a firm with higher leverage. One method providing insight into a firm's ability to raise capital to pay for disposal costs is to estimate the change in a firm's long-term debt to total capitalization percentage that would result from these disposal costs, assuming that the cost is financed totally with debt.

We performed a capital availability analysis for the individual companies in the uranium industry. The computation of the debt capitalization ratios, before and after control costs, forms the basis of this analysis. The difference in these ratios is an indication of the degree of difficulty each company might have in obtaining the necessary capital for tailings disposal. The companies are grouped according to their degree of difficulty, based on appropriate cutoff points. The analysis is explained below.

Table 5.11. Sales for Companies in the Uranium Industry
($ in millions)

	Year	American Nuclear	Atlantic Richfield	Atlas	Conoco	Exxon	Federal Resources	Getty (Petrotomics)	Homestake
Total Company Revenues	1978	1.6	12,738.8	53.3	9,871.8	63,896.0	18.3	3,758.0	170.3
	1979	10.0	16,676.7	70.9	13,083.9	83,555.0	20.4	5,121.0	234.8
	1980	5.6	24,155.6	95.3	18,766.3	108,449.0	23.8	10,437.0	345.5
	1981	6.8	28,208.3	NA	NA	113,220.3	10.2	13,252.0	262.3
	1982	6.5	26,990.6	NA	NA	102,058.9	9.3	12,312.0	198.6
Uranium Segment Revenues	1978	.4		26.8	13.7				44.9
	1979	8.2		38.3	16.3				42.4
	1980	2.0		60.1	34.4				45.4
	1981	.6		NA	NA				60.0
	1982	.6		NA	NA				63.7
Percent Uranium Revenues/ Company Revenues	1978	23.4		50.4					26.4
	1979	82.3		54.0					18.1
	1980	35.1		63.1	< 1.0		100.0		13.1
	1981	8.8		NA	NA				22.9
	1982	9.2	< 1.0	NA	NA	< 1.0		< 1.0	32.1

	Year	Kerr-McGee	Newmont (Dawn)	Phelps Dodge (Western Nuclear)	Pioneer	Rio Algom[a]	Standard Oil of Calif. (Chevron)	Standard Oil of Ohio	UNC	Union Carbide
Total Company Revenues	1978	2,072.4	685.2	1,007.5	556.0	576.1	24,106.0	5,197.7	246.7	7,870.0
	1979	2,683.5	867.6		732.5	710.7	30,938.0	7,916.0	291.7	9,177.0
	1980	3,477.9	881.6	1,502.7	912.0	847.5	41,553.0	11,702.0	274.0	9,994.0
	1981	3,826.4	903.1	1,518.9	1,224.6	918.3	45,229.0	14,667.0	277.0	10,168.0
	1982	3,777.2	711.6	1,007.5	1,118.7	760.2	35,218.0	13,842.0	354.3	9,061.0
Uranium Segment Revenues	1978	115.2		43.0	13.8	153.1			133.2	
	1979	163.4	12.0		20.2	157.2			181.6	
	1980	238.9	14.7		7.8	225.9			167.8	
	1981	201.5	13.2		7.2	281.9			102.1	
	1982	153.1	6.8		.4	281.7			84.0	
Percent Uranium Revenues/ Company Revenues	1978	5.6		4.3	2.5	26.6			54.0	
	1979	6.1	1.4		2.8	22.1			62.3	
	1980	6.9	1.7		0.9	26.7			61.3	
	1981	5.3	1.5		.6	30.7			36.9	
	1982	4.1	1.0		.03	37.1	< 1.0	< 1.0	23.7	< 1.0

NA - Not Available

[a] Canadian and U.S. operations.

Source: Companies' Annual Reports or from Form 10-K.

The starting point in the calculations begins with the no-control cost situation. The financial data used for this analysis is for the entire company, not just a subsidiary or a segment of the firm involved in the uranium business. By considering the resources of the entire company, a more realistic appraisal of the ability to raise capital is possible because the total financial resources of the firm can be used to secure credit. The parent corporation for each uranium mill is listed in Appendix D. The debt ratio is calculated for each company by dividing long term debt by its total capitalization (sum of long term debt and shareholders equity). This result represents the debt ratio before control costs. These ratios for 1982 are presented for each company in the first column of Table 5.12. An example of the calculation is as follows: The Atlantic Richfield Company (ARCO) shows long term debt of $3,500.8 million in 1982 and shareholders equity of $9,868.3 million. Total capitalization is, therefore, $13,369.1 million. The debt ratio is 26.2 percent ($3,500.8 million divided by $13,369.1 million).

In order to estimate the impact of control costs for a specific firm, two assumptions were made. First, the control costs that are used are the existing tailings costs associated with the model mills - they are not firm specific. The costs for each firm are those model pile costs that are applicable for the particular size of the tailings pile which we have estimated for each mill. Table A-3 in Appendix A lists the existing mills by the size of the tailings pile. Second, we assumed that the control costs occur entirely in a single year.

The control costs to be considered in this analysis are those associated with control methods C3 and C5. Method C5 is the most expensive control technique for existing tailings piles and represents a "worst case" scenario. These model pile costs (millions of 1983 dollars) are as follows:

	Tailings Pile Size		
Control Method	2 (10^6MT)	7 (10^6MT)	22 (10^6MT)
C3	8.3	14.3	26.8
C5	13.3	22.2	40.2

In order to compute the debt ratio after control costs, the costs of control must be added to both the debt amount and to total capitalization. As an example, for ARCO, using the controls associated with C3, it can be seen from Table A-3 that the Anaconda (a subsidiary of ARCO) pile is of the 22 million metric ton size and has control costs of $26.8 million. This amount is then added to the debt amount of $3,500.8 million, resulting in $3,527.6 million. The total capitalization is now $26.8 million plus $13,369.1 or $13,395.9 million. Dividing $3,527.6 million by $13,395.9 million results in 26.3 percent, or an

Table 5.12. Capital Availability Analysis: Debt/Total Capitalization Ratios for Firms with Existing Tailings Piles

Consolidated Corp.	Before Control Costs (1) Debt/Total Capitalization 1982 (Percent)	(2) Average[1] Debt/Total Capitalization (Percent)	After Control Costs (3) Debt/Total Capitalization for C3 (Percent)	(4) Increase in Debt Ratio with Controls (C3) (3)-(1)	(5) Debt/Total Capitalization for C5 (Percent)	(6) Increase in Debt Ratio with Controls (C5) (5)-(1)
Atlantic Richfield Co.	26.2	28.9	26.3	0.1	26.4	0.2
Atlas Corp.	0	30.9	16.7	16.7	23.7	23.7
Standard Oil of Cal. (Chevron)	7.2	10.2	7.3	0.1	7.3	0.1
Conoco, Inc.	34.4	36.2[2]	34.5	0.1	34.5	0.1
Pioneer Corp.	48.5	41.3	49.5	1.0	50.1	1.6
Commonwealth Edison	52.4	53.2	52.4	0	52.4	0
Newmont Mining Corp.	13.9	14.5[3]	14.3	0.4	14.6	0.7
Exxon Corp.	13.8	15.2	13.8	0	13.9	0.1
Federal Resources Corp.	18.8	7.4[3]	85.1	66.3	89.8	71.0
American Nuclear Corp.	56.8	47.5	71.7	14.9	76.1	19.3
Homestake Mining	.8	.4	7.7	6.9	30.4	29.6
Kerr-McGee Corp.	30.8	27.9	33.6	0.8	33.9	1.1
General Electric Co.	9.1	11.0	9.2	0.1	9.2	0.1

Table 5.12. Capital Availability Analysis: Debt/Total Capitalization Ratios for Firms with Existing Tailings Piles (continued)

	Before Control Costs		After Control Costs			
Consolidated Corp.	(1) Debt/Total Capitalization 1982 (Percent)	(2) Average$^{(1)}$ Debt/Total Capitalization (Percent)	(3) Debt/Total Capitalization for C3 (Percent)	(4) Increase in Debt Ratio with Controls (C3) (3)-(1)	(5) Debt/Total Capitalization for C5 (Percent)	(6) Increase in Debt Ratio with Controls (C5) (5)-(1)
Getty Oil Co.	19.8	10.9	19.9	0.1	19.9	0.1
Rio Algom Limited	22.1	18.1$^{(3)}$	23.0	0.9	23.6	1.5
Union Pacific Corp.	38.3	38.3	31.6	38.4	0.1	0.2
Southern Calif. Edison Co.	48.1	48.9	48.2	0.1	48.2	0.1
Standard Oil Co. (Ohio)	34.5	46.5	34.6	0.0	34.6	0.1
Reserve Oil & Minerals Corp.	0	6.7	75.5	75.5	83.1	83.1
Union Carbide Corp.	32.0	29.6	32.1	0.1	32.2	0.2
UNC Resources, Inc.	42.5	34.7	44.2	1.7	45.2	2.7
Phelps Dodge	40.6	38.9	41.1	0.5	41.3	0.7

(1) The average ratio represents a five year average from 1978 to 1982 except if noted otherwise.

(2) The average debt ratio is for the years 1981 and 1982 for Dupont which acquired Conoco in 1981.

(3) The average represents the four-year period from 1979 to 1982.

increase of 0.1 percent in the no-control debt ratio. In this particular case, because ARCO is such a large company, the addition of the control costs causes a very small impact on ARCO's debt level. The results of these calculations are shown in column (3) of Table 5.12 while column (5) presents the debt ratios using C5 as the basis for control. Three companies, Union Carbide, Exxon, and Western Nuclear (Phelps Dodge), each have two mills, so the appropriate control costs are summed for the two mills and then added to the no-control values. For mills that are jointly-owned by two companies, the control costs were split equally and assigned to each company.

The results of these calculations can be better understood by examining the change in the ratios due to tailings disposal costs. These differences are shown in columns (4) and (6) as percentage point changes. It is also helpful to compute an average debt ratio over a period of five years in order to eliminate the effect of an unusually low or high value for any given year. Such an unusual value does represent the financial situation of a firm for that particular year, but may not represent the norm. An average value smooths out these aberrations, the results of which are shown in column (2).

After examining the results of Table 5.12, it is possible to divide the companies into three groups, according to the degree of difficulty that they would have in obtaining capital. The first group consists of those firms who would experience little or no difficulty in obtaining the necessary capital. Their debt ratios increase by less than five percentage points, and their debt ratios with controls are below 40 percent. The second group of companies may have some difficulty in raising the required capital as their debt ratios increase significantly in either absolute amounts or compared to historical levels. The firms in the third group are having financial problems and would probably be unable to raise the necessary capital. This grouping of companies is shown in Table 5.13.

The cutoff points of a five percentage point difference in the debt ratio and the 40 percent debt ratio level have been derived by examining the financial data of the firms in the industry over the last five years. It is evident that for most firms in the industry the debt ratios are below 40 percent and the addition of control costs causes the debt ratio to increase by less than five percentage points. A historical review of the financial data shows that changes of about five percentage points are not uncommon. Those firms that exceed these limits generally do so to a great degree so that this cutoff point appears to clearly divide the firms according to impact.

The majority of the companies fall into the first group, with minimal or no impact as a result of either disposal method. These companies are for the most part very large diversified firms. The increase in the debt ratio with controls (either C3 or C5) is readily manageable, generally less than five percentage points. The debt ratios for these firms do not

Table 5.13. Capital Availability Analysis: Grouping of Firms by Degree of Capital Availability Problems (percentage points)(a)

GROUP 1: Minimal or No Impact in Meeting either C3 or C5	Increase in Debt Ratio with Controls (C3)	Increase in Debt Ratio with Controls (C5)
Commonwealth Edison	-	-
Standard Oil Co. (Ohio)	.1	0.1
Standard Oil of Cal. (Chevron)	.1	.1
Exxon Corp.	0	.1
Getty Oil Co.	.1	.1
Southern Calif. Edison Corp.	.1	.1
Conoco, Inc.	.1	.1
Union Pacific Corp.	.1	.2
Atlantic Richfield Co.	.1	.2
General Electric Co.	.1	.1
Newmont Mining Corp.	.4	.7
Union Carbide Corp.	.1	.2
Rio Algom Limited	.9	1.5
Phelps Dodge	.5	.7
Kerr-McGee Corp.	.8	1.1
Pioneer Corp.	1.0	1.6
UNC Resources	1.7	2.7
GROUP 2: Some Difficulty in Meeting C3 and Significant Problems in Meeting C5		
Atlas Corp.	16.7	23.7
Homestake Mining	7.3	10.5
GROUP 3: Significant Problems in Meeting Either C3 or C5		
American Nuclear Corp.	14.9	19.5
Reserve Oil & Minerals Corp.	75.5	83.1
Federal Resources Corp.	67.3	71.0

(a) Percentage point changes are taken from Table 5.12.

- = negligible impact (below .1 percentage points).

exceed 40 percent in either case, a level generally considered to be reasonable. The two utility companies, Commonwealth Edison and Southern California Edison, have ratios that exceed 40 percent before controls. However, because utility companies have a stable revenue stream, they are able to incur relatively high levels of debt. Therefore, these debt ratios can be considered as typical of their industry.

The two companies in Group 2 may have difficulty in obtaining the necessary capital. Homestake Mining Co. has had a strong profitability record during the past five years, and they have used almost no long term debt. Their highest debt ratio was in 1982 and it was extremely small, 1.6 percent. They have a large tailings pile which would result in debt ratios of 8.9 percent for C3 and 12.1 percent for C5. The Atlas Corporation presents a similar situation. Their debt ratio changes from a no-control ratio of 0 percent to 16.7 percent with C3, and 23.7 percent with C5. Both of these debt levels represent a large increase. Although the debt ratios for the two companies are roughly the same as, or below, many companies in the industry, for a company that has historically preferred to carry very little debt, the financial community may hesitate to extend this level of debt. However, an examination of their financial statements shows that a significant portion of the control costs could be financed with retained earnings, which would reduce their need for external financial markets. It should also be noted that Homestake's major activity is gold production. Therefore, their financial health rests mainly on the status of the gold market. Assuming that the company's financial outlook remains good, by using a combination of retained earnings and debt, they should be able to obtain the necessary capital.

The last group, Group 3, consists of three companies, all of which are experiencing financial difficulties even in the absence of control costs. Their financial difficulties are made worse by the addition of control costs. These companies, American Nuclear, Federal Resources, and Reserve Oil and Minerals, derive their major source of revenues from the production of uranium and have been directly affected by the declining uranium market. Federal Resources and American Nuclear, partners in the Gas Hills, Wyoming, mill, have experienced net losses during fiscal 1982 (Federal Resources had a net loss in 1981 as well) and both had declines in sales from the previous year. Reserve Oil and Minerals Corp. has had net operating losses for four consecutive fiscal years, 1979 through 1982. During fiscal year 1981 they also had negative net worth. Reserve Oil is a partner with the Standard Oil Company of Ohio in the Seboyeta, New Mexico, mill. For all three companies, the impact of control costs results in excessively high debt ratios as shown in Table 5.12. These companies are in such poor financial health that any significant amount of external financing is not feasible, and financing by retained earnings is also impossible.

5.2.3 Regional Impact

In Chapter 2, we stated that uranium mining and milling occurs in the western States of Colorado, New Mexico, Texas, South Dakota, Utah, Washington, and Wyoming. Therefore, the economic impact of controls will be concentrated in western United States. The economic impacts associated with a mill closure depend on the characteristics of the site and the region where the mill is located. In our generic analysis, we have not identified specific mills that are subject to potential closure due to the EPA standards. Consequently, it is impossible to accurately estimate the extent of the impacts that could arise. Nevertheless, we analyzed the regional impact by using a model region. We assumed a model region that is characteristic of the regions where the mills are located. The model region is likely to differ, in some characteristics, from any specific actual region. The boundary defining the area receiving the majority of the potential economic impact is an 80 kilometer (50 mile) radius around the mill. Table 5.14 describes the population characteristics of the model region, broken down into two subregions - a circular inner subregion with a 40 kilometer radius around the mill, and an outer ring from 40 to 80 kilometers around the mill. Table 5.15 describes the assumed economic characteristics of the region. The regional impact estimation procedure assumes that mill closures due to control costs are permanent, although, as described in Appendix B, there are some mills that may close temporarily based on market conditions and then reopen when market conditions improve.

If mill closures occur, the potential impacts include reduced employment, reduced tax receipts, and reduced property values. The effects of a mill closure go beyond the loss of employment at the mill and the revenues of the mill, for they have repercussions on the economy of the region. The total economic impact of mill closures on a region is composed of three effects: direct, indirect, and induced effects. The direct effects include the employment at the mill, the revenue of the mill, and the taxes paid by the mill. The indirect effects are the reduced expenditures by other businesses for materials used in the production process. The induced effects are reduced expenditures made by all households for final goods and services, which reduces the level of commerce in the entire region, and to a minor extent, commerce outside the region.

The direct effects of any particular impact case can be estimated by reviewing the number of model mill closures associated with the case and summing the effects for each closure. For example, if lost employment due to model mill closures is of interest, and three model mills are projected to close, then the direct loss of employment is simply the sum of the employment for the three model mills. The total employment effect (direct, indirect, and induced) can be estimated by applying a multiplier to the direct effect. Multipliers are developed for estimating the total

Table 5.14. Demographics of the Model Uranium Mining and Milling Region

	Distance from Mill (Km)	Area (Km^2)	Population 1960	Population 1976	% Increase 1960-1976	Current Labor Force
Inner Subregion	0-40	5,000	1,920	2,200	15	-
Outer Subregion	40-80	15,000	47,560	55,100	16	-
Total Region	0-80	20,000	49,480	57,300	16	20,800

Source: U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, September 1980.

Table 5.15. Economic Characteristics of the Model Region

Industrial Sector	% Employed By Sector[a]	Sector Employment	Sector Payroll[b] (million 1982 $)
Manufacturing	5.0	1,040	18.39
Wholesale and Retail Trade	18.7	3,890	51.20
Government	21.8	4,534	60.32
Services	13.1	2,725	38.66
Transportation and Public Utilities	7.5	1,560	33.06
Finance, Insurance, Real Estate	3.0	624	8.68
Contract Construction	8.8	1,830	43.43
Mining	11.2	2,330	52.44
Agriculture	10.9	2,267	43.84
Total	100.0	20,800	350.02

(a)Source: U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, September 1980. The original NRC distribution was adjusted to include agriculture.

(b)Sector payroll equals average wage in sector times sector employment. Average wage was obtained from U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1982.

economic impact on a region resulting from a change in income or employment in a specific industry. The values assumed for a multiplier may change according to the characteristics of the region and the industry investigated. A multiplier of 2.21 is used to represent the total impact on employment and 1.97 to represent the total impact on payroll earnings in the Western United States(EMJ81).

The impacts on employment and payroll in the model region are presented in Table 5.16. The direct impacts on employment resulting from a mill closure range from a decrease of 70 employees for a small model mill to 280 employees for a large model mill. Total employment impacts range between 155 and 619 employees resulting from the closure of a small or large model mill, respectively. Because of the relatively small size of the work force in the model region, the unemployment rate will be impacted significantly, with a range of increases in the rate from 0.7 to 2.9 percent, depending on the size of the model mill closure.

The total impact on the region's payroll ranges between $3.2 million and $12.5 million, depending upon the size of the model mill. In relative terms, the impact on the region's payroll is larger than the impact on the region's work force, ranging from a decrease of 1.1 to 4.3 percent. This larger impact on the area's payroll is due to the larger than average wages and salaries received by the employees in the uranium mining and milling industry.

Additional short-run impacts on the region would include reduced tax receipts, reduced property values, and reduced personal income. However, over the long-run, these short-run problems should be mitigated as the regional economy adjusts to the mill closures and returns to equilibrium. Long-run transition mechanisms that restore equilibrium include the mobility of the work force and the influx of new industry.

5.2.4 Macroeconomic Impact

The impacts discussed in previous sections are also applicable at the macroeconomic level. However, most of these effects may be difficult, or even impossible, to discern. For example, even if the potential employment losses may be significant for the uranium industry and significant for a particular region under some cases, the effect on the national unemployment rate is not likely to be perceptible. One potential impact that could be discernible at the national level is imports of uranium.

For the most costly impact case (Case 37), we estimate that two small model mills may close. These model mills represent about 600 MT of annual U_3O_8 capacity. In our industry simulation methodology (Appendix B analysis), we assume that in response to closures due to tailings disposal, capacity from standby is reopened to avoid a shortfall in conventional mill production. In our baseline projection, we estimate

Table 5.16. Direct, Indirect, and Induced Impacts on the Model Region Resulting from a Single Model Mill Closure

Model Mill	Model Mill Size (MT)	Mill Employees[a]	Total Impact on Work Force[b]	% of Region's Work Force	Total Mill Payroll (Million $)[c]	Total Impact on Payroll (Million $)[d]	Percent of Area Payroll
Small	900	70	155	0.7	1.6	3.2	1.1
Medium	1,800	140	309	1.5	3.2	6.3	2.1
Large	3,600	280	619	2.9	6.3	12.5	4.3

(a) This cross-section of model mills assumes no economies of scale with respect to the utilization of labor. Employees per metric ton of capacity was calculated using data from U.S. Department of Energy, Statistical Data of the Uranium Industry, 1980. Mill employees equals model mill capacity times employees per metric ton of capacity.

(b) Mill employees times 2.21.

(c) Total mill payroll equals mill employee times average yearly salary per employee. Salary per employee was obtained from U.S. Department of Commerce, Bureau of the Census, Census of the Mineral Industries, 1977.

(d) Total mill payroll times 1.97.

that in 1983, there will be 4,900 MT U_3O_8 on standby. Since the amount of regulatory closures, (assumed to occur in 1984), are only 12 percent of the standby capacity in the previous year, there will be no shortfall in production over the period 1983 through 1989. After 1989, a shortfall in production is assumed to be avoided by additional new mill capacity (above the baseline projection) becoming operational. With no shortfall in production being projected, there will be no impact on the level of imports.

5.2.5 Government Subsidy

The Federal and State Governments have assumed the financial responsibility for reclamation of tailings piles at all inactive uranium mill sites under the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). The apparent reason for their assuming financial responsibility was that the mills at these sites had been operating under contracts with the Federal Government, primarily for supplying uranium to be used for defense purposes. UMTRCA was enacted into law after the life cycles of those mills had been completed, leaving no opportunity for tailings disposal control costs to be recovered through product price increases. If tailings control requirements had been imposed earlier, the mill owners would have been able to pass the control costs to their customers, i.e., the Federal Government. Thus, the government would have ultimately paid the control costs.

Many of the active mills also operated under contracts with the Federal Government between 1943 and 1970. Therefore, some of the existing tailings inventories at these sites also resulted from government contracts. The tailings resulting from these government contracts are referred to as being commingled with the tailings resulting from the mills' commercial business. The Department of Energy National Defense Programs Authorization Act of 1981 authorized DOE to assess the commingled tailings situation and report back to Congress by October 1981 with recommendations for dealing with them. DOE submitted this report to Congress in June 1982 (DOE82).

According to the DOE study, commingled tailings are located at 13 licensed mill sites. As of the end of 1981, there were approximately 125 million MT (138 million short tons) of tailings at these 13 sites, of which about 51 million MT, or 41 percent, are believed to be defense related. The DOE estimate of defense-related tailings represents about 29 percent of all the tailings (175 million MT) which we estimate have accumulated at all the licensed mills as of January 1983 (see Table 2-10).

Efforts are underway in Congress to provide financial assistance to mill owners whose sites contain commingled tailings. These efforts are based on the grounds that since the Federal Government agreed to pay for the stabilization of tailings at inactive sites which resulted from government contracts, the government should help pay for the stabilization of tailings at active sites which also resulted from government contracts. Whether or not a subsidy is justified has no effect on the development of the EPA standards and, therefore, is not discussed in this RIA. However, we have estimated the potential size of a subsidy for the different economic impact cases based on our tailings disposal cost estimates and DOE's estimate of the quantity of tailings resulting from government contracts.

To determine the amount of the subsidy for each case, we multiply an appropriate unit cost of disposal ($ per ton of tailings) by the 51 million MT of defense-related tailings estimated by DOE. The unit cost is derived by dividing our total cost estimates for disposing of all 26 existing tailings piles (from Table 5.2) by the estimated total quantity of tailings at these piles, 175 million MT. These estimates are presented in Table 5.17. Ignoring the no disposal case (Alternative Standard A), the subsidy estimates range from 45 million dollars for Case C1 to 158 million dollars for Cases C5 and D5.

Since the EPA standards are indifferent toward the establishment of a subsidy program, we have not investigated the ways in which such a program could be implemented. Also, we have not analyzed the impact that subsidies would have on the individual mills. If a subsidy program is implemented for the sites with commingled tailings, then the economic impacts resulting from tailings disposal would be diminished for those sites.

Table 5.17. Subsidy Estimates for Commingled Tailings By Alternative Standard (millions of 1983 dollars)

Alternative Standard	Amount of Subsidy
A	---
B1	46
B2	75
B3	100
C1	45
C2	75
C3	102
C4	131
C5	158
D2	75
D3	102
D4	131
D5	158

REFERENCES FOR CHAPTER 5

DOE82 U.S. Department of Energy, Commingled Uranium Tailings Study, Volume I, Plan for Stabilization and Management of Commingled Uranium Mill Tailings, DOE/DP-0011, June 30, 1982.

EMJ81 Engineering and Mining Journal, "Can Changes be Made that Will Encourage Mine Development?" May 1981.

6. Selection of Standards

There are two major parts of the standards, as discussed in Chapter 1: control of releases from tailings during processing operations, and permanent control of tailings through final disposal. Since most of the requirements for operations are already in existence, through regulations promulgated under the AEA, the CWA, and the SWDA (as required under the Act), alternative standards for operations are not considered in this analysis. However, these existing standards (which are supplemented in these standards by a few additional criteria specific to uranium tailings) are summarized in section 6.1 to show that all identified environmental threats from tailings are or will be controlled. Comments received on the proposed standards during operation are reviewed and responded to in section 6.1.

Section 6.2 deals with standards for disposal and includes a summary of material presented in this RIA and in the FEIS.

6.1 Operations Standards

Particulate Emissions

Radioactive particulate emissions from uranium mill tailings piles during the operational phase of the mill are currently controlled by EPA's Uranium Fuel Cycle Standards (40 CFR Part 190). These standards limit the annual radiation dose to members of the public to 25 millirem to the whole body or any organ (except the thyroid, which is limited to 75 millirem) as a result of discharges to the general environment from uranium fuel cycle operations. Uranium mills, including the tailings piles, are included in uranium fuel cycle operations, as defined in the standards.

The American Mining Congress has previously petitioned EPA to relax these standards at milling operations, and this petition is still under consideration. No significant new comments were received concerning the existing standards for particulate emissions.

Radon Emissions

Control of radon emissions from uranium mill tailings is not currently included in EPA standards. Radon and its decay products were excluded from 40 CFR Part 190 because, at that time, considerable uncertainty existed about the feasibility of controlling radon emissions from tailings piles. EPA concluded that the problems associated with controlling radon emissions were sufficiently different from those of other radionuclide emissions associated with the uranium fuel cycle to warrant separate consideration at a future time. Radon concentrations in air in unrestricted areas resulting from emissions from uranium mill tailings are currently limited by NRC's Standards for Protection Against Radiation (10 CFR Part 20). These standards, which are derived from the Federal Radiation Protection Guidance (25 FR 4402), limit the radon concentration in air in areas to which individual members of the public have access to 3 pCi/l. Areas in which unlimited permanent residence by large numbers of people is possible are limited to one-third of this value, or 1 pCi/l, by Federal Radiation Protection Guidance.

The proposed rule required that the regulatory agency apply the ALARA principal in establishing management procedures and regulations to control radon from operating mills. This approach was proposed because EPA concluded that numerical standards to control radon were not reasonable during operations. This is because practical methods for reducing radon emissions during operations of existing mills and piles (which are limited in effectiveness to a factor of 2 or 3) are of different effectiveness, depending on site-specific characteristics, and because there are large variations in the effectiveness possible at different stages of the growth of a given pile. The primary means for controlling radon emissions from existing tailings piles during operations is to keep the tailings as wet as possible and optimize the speed at which tailings are disposed.

Some commenters indicated that the provisions of the proposed rule were inadequate to assure that the public would be protected. They argued that EPA has the responsibility under both UMTRCA and the Clean Air Act to provide suitable health protection to all members of the public. They suggested that directly requiring certain tailings management practices would (rather than depending upon the NRC to require them as implementation of ALARA) provide greater public health protection than the provisions of the proposed rule. For example, they note that "staged" or "phased" disposal of tailings and good water management practices should be required by EPA standards.

EPA has concluded that it may be desirable to provide greater assurance that radon releases will be minimized during milling operations than is provided by the proposed rule. The Agency has not performed sufficient analysis of work practice and tailings management techniques to determine whether they are always suitable for this purpose and which alternatives are best. Therefore, the Agency is publishing, in a separate Federal Register notice, an Advance Notice of Proposed Rulemaking under the Clean Air Act for consideration of standards for the control of radon emissions from uranium tailings piles during the operational period of a uranium mill. The ANPR will enable the Agency to gather information on the feasibility, effectiveness, and cost of various alternatives that would control radon releases from operating mills. This will enable EPA to be better informed when judging whether standards are needed, and if so, what the most suitable requirements should be.

Discharges to Surface Waters

Wastes are currently discharged to surface waters at only one site. Such discharges are not necessary in most uranium mining regions because annual natural evaporation is greater than precipitation. Liquid wastes can therefore be stored in a pond, lined to prevent seepage into groundwater, and allowed to evaporate.

EPA is continuing to implement the requirements of the Clean Water Act. EPA's programs for new source performance standards (NSPS) are now aimed principally at control of toxic pollutants. Regulations are now in effect which define best practicable technology (BPT) for wastewater discharges from existing mills and new source performance standards (NSPS) for control of discharges from new mills using the acid leach, alkaline leach, or combined acid and alkaline leach process for the extraction of uranium (40 CFR Part 440). As an example of these regulations, the NSPS requires that "There shall be no discharge of process wastewater from mills using the acid leach, alkaline leach, or combined acid and alkaline leach process for the extraction of uranium or from mines and mills using in-situ leach methods."

Several commenters from Virginia and Illinois expressed concern regarding the applicability of the standards to wet sites, i.e., locations where annual average precipitation exceeds annual average evaporation. EPA stated in the Federal Register notice accompanying the proposed standards that if uranium mining and milling is conducted in wet regions, the adequacy and appropriateness of the standards may have to be reviewed, particularly the water protection requirements. Based on this statement, the commenters were concerned that EPA intended to apply less stringent standards for tailings control at wet sites.

Our remarks concerning wet sites in the Preamble for the proposed standards were mainly intended to acknowledge that U.S. uranium mills are in arid and semi-arid areas, and that we have little operating experience with control measures needed to comply with the standards under wet, as opposed to under dry, conditions.

The final standards should provide adequate environmental and health protection for uranium milling in all regions of the United States. The basic groundwater protection provisions during operations have been modified to provide for protection against the "bathtub" effect (accumulation of water in the wastes) at sites in wet regions. These provisions are identical to those that were developed at EPA for national application to hazardous waste sites. The New Source Performance Standards, 40 CFR 440.34, protects surface water by prohibiting discharges from new mills except for the amount by which precipitation may exceed evaporation. Any discharged water must satisfy concentration standards corresponding to use of the best available demonstrated treatment technology. In addition, specific limits are established under these standards for discharges of zinc, radium-226 (dissolved and total), uranium, and total suspended solids.

EPA believes these and the other provisions of the final standards will provide adequate protection for wet and dry areas, considering differences in both net precipitation and population density.

Groundwater Protection

The Act requires that the standards for nonradiological hazards protect human health and the environment in a manner consistent with the standards required under subtitle C of the Solid Waste Disposal Act (SWDA), as amended (Section 275b(2)). The Act also directs the NRC to develop regulations to implement these standards that are in conformance with the SWDA (Section 84a(3)). Specifically, this section directs the NRC to "...insure that the management of any uranium tailings conforms to general requirements established by the Commission, with the concurrence of the Administrator, which are, to the maximum extent practicable, at least comparable to requirements applicable to the possession, transfer, and disposal of similar hazardous material regulated by the Administrator under the Solid Waste Disposal Act, as amended."

Standards for nonradiological hazards under subtitle C of SWDA are part of a comprehensive regulatory program to protect human health and the environment from hazardous waste disposal in or on the land. This program includes identification and listing of hazardous materials, a manifest system to track hazardous materials from cradle to grave, controls for the transportation of hazardous materials, standards for owners and operators of hazardous waste treatment, storage and disposal facilities, and a permitting system for the treatment, storage, and disposal of hazardous waste. EPA's role for control of hazardous materials from uranium tailings under this Act is limited to setting standards and does not include a regulatory responsibility. That responsibility is vested in the NRC and the States as the licensing agencies under Title II of the Act.

The purpose of the SWDA groundwater protection regulations is to assure that groundwater quality is compatible with the various uses to which it may be put, so that reasonable assurance exists that human health and the environment will be protected. To accomplish this, the fundamental goal of the regulations is to minimize the migration into the environment of the hazardous component of the waste placed in land disposal units. EPA's strategy for achieving this goal has two basic elements. The first element is a liquids management strategy for disposal units that is intended to minimize leachate generation in the waste management units, to provide an impermeable barrier between the waste unit and the subsurface, and to remove leachate from these units before it can enter the subsurface environment. This is the "first line of defense" in the sense that it seeks to prevent groundwater contamination by controlling the source of the contamination. The second element of the general strategy is a groundwater monitoring and response program that is designed to remove leachate from the groundwater if it is detected. The monitoring and response program serves as a backup to the liquids management strategy and would be established by regulations set by the NRC, with the concurrence of the Administrator, upon promulgation of these standards by EPA.

Numerous comments were received regarding the proposed standards for groundwater protection. These comments are classified as: (i) Shared responsibilities between EPA and NRC; (ii) Choice of liner material; (iii) Alternative concentration limits; (iv) Timing of corrective actions; (v) Nonhazardous materials contamination of groundwater; and (vi) neutralization of tailings. Each class is discussed below.

(i) Shared Responsibilities between EPA and NRC

EPA recognized, in proposing these standards, that the Act establishes a shared responsibility between EPA and NRC for assuring groundwater protection. EPA attempted to reach a balance on this issue by assigning health protection standards-related responsibilities to EPA and technical/engineering implementation-related responsibilities to NRC. This is consistent with the traditional role of each agency over the past three years. Thus, EPA proposed to retain authority to allow deviations from standards through a concurrence role for exemptions and alternative standards for specific sites.

Regarding the technical/engineering responsibilities, EPA chose to impose only one requirement - that new tailings impoundments or additions to existing impoundments install a liner to provide groundwater protection. We believe this requirement mandatory since it is the primary standard under the SWDA regulations. Other than this requirement (and the choice of lining materials, alternative concentration limits, and the timing of corrective actions, as discussed below), EPA delegated to NRC the responsibility for exemptions to the liner requirement and the approval of monitoring schemes. We believed this was a reasonable split of the shared responsibilities for groundwater protection.

NRC commented that it believed EPA's nondegradation policy for groundwater protection was overly restrictive and that EPA's proposed retention of a concurrence role for exemptions and alternative standards for groundwater appeared to be in conflict with the proviso in Section 275b.(2) of the AEA, as amended, that no EPA permit (under SWDA) is required. The NRC suggested that a consistent reading of Sections 84a.(3) and 275b.(2) allows EPA some latitude in formulating a groundwater protection standard that is less rigid and more realistic for uranium mill tailings impoundments than the proposed standards. In support of their opposition to the combined EPA concurrence role and the nondegradation standard, the NRC stated they will be required to consider exemptions in practically every case, not just occasionally.

EPA has a basic goal of protecting groundwater resources for future uses and has applied this throughout its rules affecting activities that may pollute groundwater. The circumstances surrounding this rulemaking do not appear to be significantly enough different from previous cases to warrant modifying this approach. Therefore, EPA has concluded the goal for protection of groundwater, i.e., nondegradation, should be retained in this rule.

The proposed retention of an EPA role in issuing alternative standards or exemptions for groundwater was based on EPA's responsibility to establish standards that would assure health protection. EPA believes this responsibility cannot be delegated. However, EPA is modifying the concurrence role for issuing alternative concentration limits (see below) which will reduce the administrative burden for noncompliance situations.

(ii) Choice of Liner Material

In proposing to adopt the SWDA primary standard, the liner requirement under Subpart K of 40 CFR 264, EPA recognized that the plastic liner requirement might not be a suitable choice at all tailings impoundments. Consequently, comments were solicited regarding this requirement in the April 29, 1983 notice.

Some commenters responded that they knew of no liner technology capable of achieving the goal of the liner requirement, i.e., no seepage of hazardous constituents into the soils underlying an impoundment, or groundwater, or surface waters. Others testified that clay liners could be expected to perform as well or better (in terms of reliability against catastrophic failure) as plastic liners in protecting groundwater. Still others testified that double liners, incorporating both clay and plastic, were the appropriate control technology.

We have concluded that this technical controversy is not yet resolved and that it would be inappropriate for EPA to make a judgment on the exact mechanism to be used for achieving containment of leachates. We, therefore, have left the existing SWDA requirement unchanged. This requirement, which requires a non-porous liner, also contains detailed provisions (264.221(b)) which will permit use of other means for containing leachates if it can be demonstrated that groundwater will be protected (i.e., meet the standards established by this rule).

(iii) Alternative Concentration Limits

Several commenters stated that groundwater beneath tailings piles would exceed the standards at essentially all existing sites. Thus, the groundwater standard would be exceeded in nearly all cases. A major reason for this problem is that many of the piles have been in use for years, extending back to the period before NRC increased regulatory requirements in the late 1970's to require liners.

EPA recognizes that incorporation of the SWDA rule specifying non-degradation at the edge of the waste (the tailings) would make most existing piles not in compliance. This would require exemptions or alternative standards or the initiation of corrective actions for most piles.

An important difference between requirements under UMTRCA and SWDA is that the title to the land which is used as a disposal site under UMTRCA must be transferred to the United States or the State in which such land is located. The SWDA has no such requirement. Since the government will control land used for tailings disposal, EPA believes there is sufficient justification to provide flexibility regarding the point of compliance.

Therefore, we have changed the rule to allow NRC to issue alternative concentration limits without requiring EPA concurrence when the secondary standards are met within 500 meters, or the disposal site boundary, whichever is less from the edge of the tailings at existing sites.

(iv) Timing of Corrective Actions

Some concerns were expressed regarding the proposed requirement to put corrective actions for restoration of groundwater quality into operation as soon as practicable, and in no event later than one year, after a noncompliance determination is made by the regulatory agency. The major concern appears to be that it may take longer than one year to devise and implement an effective corrective action. The geohydrological characteristics also vary greatly from site to site. This can also influence the timing of corrective actions.

Based on these considerations, EPA concluded that it would be appropriate to extend the time limit for implementation of corrective actions to eighteen (18) months. However, the requirement for submittal of an application for a license amendment within 180 days to establish a corrective action program, as required under the SWDA rule 264.99(i), remains unchanged.

(v) Nonhazardous Materials Contamination of Groundwater

Comments were received on two different aspects regarding the contamination of groundwater by nonhazardous materials. (They include chlorides, sulfates, manganese, and total dissolved solids, among others.) At high concentrations, these materials can make water unfit for use for other than health-related reasons.

One comment on these materials was that several of them are more mobile than hazardous materials. Thus, they precede hazardous materials in contaminating groundwater. Groundwater monitoring for these materials allows the prediction of future groundwater contamination by hazardous materials. This detection scheme would, therefore, provide an early warning of groundwater contamination and allow early corrective actions to be taken, thereby effectively preventing ground contamination by hazardous materials.

EPA agrees with this comment. Analyzing water samples for substances from tailings that are expected to be the most mobile in a given groundwater environment is a very useful site-specific monitoring requirement. The regulatory agencies may establish such requirements whether or not EPA sets standards for nonhazardous substances. Therefore, we did not set standards for substances that do not endanger human health.

A second view held that much of the groundwater in the western States is already contaminated with nonhazardous materials to an extent that it is unsuitable for use. These are primarily shallow aquifers (or uppermost aquifers) which would be the first to be contaminated by tailings piles materials. Since these groundwaters are already contaminated, it was argued that there is no need to prevent additional contamination.

This comment would require changing the groundwater protection policy EPA has established under the SWDA rules. These standards are required to be consistent with the SWDA rules to the extent reasonable under UMTRCA. We do not believe this rulemaking is the appropriate forum to reconsider basic EPA policy on groundwater protection.

(vi) Neutralization of Tailings

Some commenters recommended that EPA require neutralization of tailings as a method to protect groundwater. Neutralization is chemical treatment that would make the tailings neither acid nor alkaline. When neutral, most constituents in the tailings precipitate or react with surrounding material (earth at the bottom of the impoundment) and thereby are less prone to move through the earth and into groundwater.

EPA conducted a study of tailings neutralization in 1980, as discussed in the DEIS. Two major problems were identified regarding neutralization. First, some of the hazardous constituents in tailings form complex compounds that remain mobile, i.e., they do not react with surrounding material but remain in solution, over wide ranges of acidity/alkalinity conditions. Selenium, arsenic, and molybdenum - all constituents of tailings - behave this way. It is not clear that adequate control can be achieved, even given careful operation of the neutralization process, considering the large volumes of tailings.

Second, the costs of neutralizing the tailings are significant, about the same as installation of a liner. Most of the cost is due to the need for a sludge storage lagoon. Also, neutralization would not preclude the need for a liner.

EPA is limited in its authority under the Atomic Energy Act and UMTRCA to establishing generally applicable environmental standards. Generally, this does not include requirements for specific control methods, such as neutralization.

In view of these issues, EPA concludes that requiring neutralization of tailings was inappropriate through these standards. We note that the standards do not prohibit such treatment, but leave this decision to the regulating agencies.

6.2 Disposal Standards

6.2.1 Overview

The radioactivity and toxic materials in tailings may cause cancer and other diseases, as well as genetic damage and teratogenic effects. More specifically, tailings are hazardous to man primarily because: (1) radioactive decay products of radon may be inhaled and increase the risk of lung cancer; (2) individuals may be exposed to gamma radiation from the radioactivity in tailings; and (3) radioactive and toxic materials from tailings may be ingested with food or water. The first of these hazards is by far the most important.

The radiation hazard from tailings lasts for many hundreds of thousands of years, and some nonradioactive toxic chemicals persist indefinitely. The hazard from uranium tailings, therefore, must be viewed in two ways. Tailings pose a present hazard to human health. Beyond this immediate but generally limited health threat, the tailings are vulnerable to human misuse and to dispersal by natural forces for an essentially indefinite period. In the long run, the future risks to health of indefinitely extended contamination from misused and dispersed tailings overshadow the short-term danger to public health. The Congressional report accompanying UMTRCA recognized the existence of long-term risks and expressed the view that the methods used for disposal should not be effective for only a short period of time. It stated: "The committee believes that uranium mill tailings should be treated...in accordance with the substantial hazard they will present until long after existing institutions can be expected to last in their present forms..." and, in commenting on the Federally-funded program to clean up and dispose of tailings at the inactive sites, it stated "The committee does not want to visit this problem again with additional aid. The remedial action must be done right the first time." (H.R. Rep. No. 1480, 95th Congress, 2nd Session, Pt. I, p. 17, and Pt. II, p. 40 (1978).)

Based on a review and analysis of the risk to public health and the environment posed by uranium mill tailings, EPA concludes that the primary objective of standards for control of hazards from tailings through air pathways is isolation and stabilization to prevent their misuse by man and dispersal by natural forces, such as wind, rain, and flood waters. The second objective is to minimize radon emissions from tailings piles. A third objective is the elimination of significant exposure to gamma radiation from tailings.

The primary objective of standards for control of hazards from tailings through water pathways is to prevent loss of process water through seepage, prior to closure. A secondary objective is to avoid surface runoff and infiltration both before and after disposal.

Various methods are available to achieve these objectives. EPA has reviewed disposal methods and concluded that earth covers were likely to be the method used in most cases. The descriptions and costs of alternative levels of control have been presented in earlier sections of this RIA and the FEIS. After reviewing these alternatives, EPA concludes that a radon emission limit of 20 pCi/m^2s, which should be effective for 1,000 years, is reasonable and provides an ample margin of safety for protection of health. The rationale for this selection is discussed below. Groundwater is protected at dry sites by the thick earthen cover needed to achieve these limits. At wet sites, a cover that is less permeable than the liner is required to protect groundwater.

6.2.2 Basis for Selection

Comments on the proposed disposal standards are discussed below under three headings: (i) Standards based on current population data, (ii) Passive vs. institutional controls, and (iii) Radon emission limit.

(i) Standards Based on Current Population Data

During the review of the standards for the inactive sites by certain Federal agencies, questions were raised regarding the appropriateness of the disposal standards for general application to all 24 inactive sites. Some reviewers suggested that less restrictive standards might be appropriate for sites that are in currently sparsely populated areas. Other reviewers suggested that we consider a radon standard that applies at and beyond the fenced boundary of such a site, i.e., a standard that relies in part on institutional maintenance of control of access. EPA requested public comments on these issues for the inactive sites (48 FR 605, January 5, 1983). These issues are most simply stated as (1) Should the degree of radon control after disposal depend in part on the size of the current local population, and (2) Should implementation of the disposal standards be permitted to depend primarily or in part on maintenance of institutional control of access (e.g., by fences)? We also specifically requested comments on these issues in the April 29, 1983 notice of proposed rulemaking for active mills. The majority of commenters who addressed this issue opposed any relaxation of the standards at remote sites. Many raised the "equity" consideration, in which the primary concern is the fairness of protecting a few people less just because of where they live.

In 1983 EPA counted the number of people living close to all the active and inactive mill sites. Of the 52 sites surveyed, only 7 had no people living within 5 kilometers (3 miles). Another 6 sites had 10 or fewer people living within 5 kilometers. Collectively, however, the mill sites have a normally distributed continuous range of local populations, and it is difficult to distinguish a special set of sites. The definition of a remote site is therefore difficult to achieve, unless it is done arbitrarily. In addition, demographers have concluded that it is not possible to determine that a population at a specific location will remain low in the future, if it is low now.

The motivation for considering relaxed standards at "remote" sites is to reduce the cost of disposal. Our analysis shows that the potential cost savings of less restrictive standards at such sites is small. We estimate that, even for the case of no radon control at all sites (case C1) and with no provision for the added costs of institutional control through fencing, land-use control, and land acquisition (to avoid unacceptably high individual doses to nearby residents), only 44 percent of the cost of disposal at the level required by these standards would be potentially recoverable. We have examined the added costs required for institutional control and conclude that they may vary from about 10 to 50 percent of the costs required by these standards, depending mostly on the cost of land acquisition at specific sites. We have concluded, therefore, independent of other considerations, that when these significant costs for institutional control are added and any net saving is applied to only those sites that might be defined as "remote," the potential total cost saved is not significant enough to warrant separate standards.

Finally, with regard to the Agency's legal authorization to establish a separate level of protection at remote sites by issuing two sets of standards, EPA is aware of no basis upon which it could provide some persons less protection than is afforded to others where the only difference between them is choice of residential location. We are also aware of no site that is uninhabited and can also reasonably be assumed will remain uninhabited. We conclude, therefore, that relaxed standards for "remote" sites are not feasible on demographic or legal grounds, and are not attractive, in any case, on the basis of cost-effectively achieving the various public health and environmental goals of this rulemaking.

(ii) Passive vs. Institutional Controls

As noted above, EPA requested comments on whether a radon limit applied at the boundary ("fenceline") of the Government-owned property around a tailings pile would be an appropriate form of standard for the sites with low nearby populations. Such a standard could be satisfied largely by institutional methods, i.e., by acquiring and maintaining control over land. The proposed disposal standard, however, can be satisfied only by generally more costly physical methods (such as applying thick earthen covers) that control the tailings and their emissions, with minimal reliance on institutional methods. EPA also requested comments on the adequacy of such a radon "fenceline" standard to meet the objectives of the UMTRCA.

Comments on this issue ranged from strong support of passive stabilization requirements for periods greater than 1,000 years to protection for only a few decades with reliance on institutional controls.

EPA's position is that protection from the long-term hazards associated with radioactive waste should primarily rely on passive control methods. We also note the intent of Congress as stated in the Congressional report accompanying UMTRCA: "The committee believes that uranium mill tailings should be treated in accordance with the substantial hazard they will present until long after existing institutions can be expected to last in their present forms." In addition, the costs of land acquisition to limit maximum individual exposures can easily negate any potential saving through use of thin covers. However, institutional control can play a useful secondary role in supplementing passive controls and in assuring, during the early period of disposal, that passive controls are adequate to achieve their design objectives.

(iii) Radon Emission Limit

Reliable quantitative estimates of health effects from tailings can be made only for radon emissions and windblown particulates. Health effects from misuse of tailings and contamination of water cannot be quantified reasonably because of the extremely high degree of uncertainty associated with the likelihood that misuse and contamination might occur and the wide range in the degree to which people are exposed to radiation and toxic substances. (For example, tailings used as fill in unoccupied areas would not result in direct human exposure. Using tailings as fill for residential buildings very significantly elevates radiation exposure and risk. The degree to which people might be exposed to contaminants from tailings through waterborne pathways is subject to similarly high uncertainties.) The health effects from radon and its decay products are much greater than from particulates, even when external radiation and food chain contributions are included in the particulate estimates. Therefore, only quantitative estimates of effects from radon emissions will be discussed further here. However, based on historical circumstances of misuse of tailings, we believe that the effects from misuse or water contamination could potentially be comparable to those from radon emissions if long-term protection is not afforded.

The primary concern of commenters who thought the proposed radon emission standard was too lax was over the risk to nearby individuals. The estimated added lifetime risk of fatal lung cancer for someone living permanently near a model pile is 1 in 1,000 at a 20 pCi/m^2s emission level. (Based on our 1983 survey, we conclude that such a person is likely to be 0.5 to 1.0 km from the edge of a pile. The survey identified a few dozen such individuals at existing piles that are expected to continue in place.)

Commenters who thought the proposed radon emission standard is too strict contended that the cost of compliance would be too high in view of the small contribution radon from tailings makes to a population's total exposure to atmospheric radon. They also generally believed EPA had overestimated the health effects of radon.

In Chapter 4, we examined the cost per radon death avoided for alternative control levels from several viewpoints. This range of viewpoints included the length of time over which health effects should be related to costs and whether low-risk nationwide population effects should be included with high-risk regional population effects in making benefit-cost comparisons. We conclude that the incremental cost per radon death avoided at a 20 pCi/m^2s emission limit is a reasonable expenditure under all scenarios. The range of incremental costs per death avoided at this control level is from $130,000 (nationwide health effects estimated for 1000 years) to $2.5 million (regional health effects estimated for only 100 years). For the next, more stringent, level of control, 6 pCi/m^2s, the incremental costs are higher: $630,000 to $12 million per radon death avoided. For the next, less stringent, level of control, 60 pCi/m^2s, the incremental costs are lower: $70,000 to $1.4 million. Whether or not the expenditure for a control level is acceptable depends on one's view of the relevant factors to be considered in valuing the benefit stream. On a relative basis, the incremental cost increases by a factor of 5 for going from the 20 pCi/m^2s limit to 6 pCi/m^2s, and increases by only a factor of 2 for going from 60 pCi/m^2s to 20 pCi/m^2s.

Selecting a limit for radon emission from tailings involves four public health objectives, in addition to reducing health effects from radon released directly from the pile. These may all be achieved by using a thick earthen cover, which serves to inhibit misuse of tailings, to stabilize tailings against erosion and contamination of land and water, to minimize gamma exposure, and to avoid contamination of groundwater from tailings. A radon emission limit of 20 pCi/m^2s or less would require use of a sufficiently thick earthen cover to achieve all of these objectives.

The risk to people who live permanently very close to tailings piles can still be relatively high, up to 1 in 1000 for lifetime residency, for a limit of 20 pCi/m^2s. However, the practicability and cost-effectiveness of providing more radon control by requiring design for lower levels of emission falls rapidly below 20 pCi/m^2s. We note that no pile has ever been protected by such a cover; that is, covers with defined levels of control and longevity are undemonstrated technology. The design of covers to meet a specific radon emission limit and period of longevity must be based on measurements of properties of local covering materials and prediction of local parameters, such as soil and tailings moisture, over the long term. Because of uncertainties in measuring and predicting these parameters, the uncertainty of performance of soil covers increases rapidly as the stringency of the control required increases. Thus, in the case of lower levels, the primary issue becomes whether conformance to a design standard for such levels is practicably achievable.

There is some information available regarding the practicality of reduction of radon emissions to levels approaching background. Tests conducted at the Grand Junction, Colorado, pile for four different thick earthen covers reduced radon emissions to values ranging from 1.0 to 18.3 pCi/m^{2}s. We believe ranges like these can be expected generally in practice since the radon control characteristics of earth used for covers will vary from site to site. If the standard were reduced to a 6 pCi/m^{2}s level, three of the four covers studied would not achieve the standard. Exactly how much thicker the cover on these three piles would need to be to achieve a lower limit (e.g., 6 or 2 pCi/m^{2}s) is not known. Experts commented during hearings on the standards that, although covers can be designed to meet such levels as 20 pCi/m^{2}s, estimation models are not reliable at significantly lower emission levels.

We concluded that achieving conformance with a radon emission standard that is significantly below 20 pCi/m^{2}s (6 or 2 pCi/m^{2}s, for example) clearly would require designers to deal with unreasonably great uncertainty for this undemonstrated technology.

The risk from these radon emissions diminishes rapidly with distance from the tailings pile (approximately one-third for each doubling of the distance beyond a few hundred meters). There currently are only about 30 individuals living so near to active piles that they could be subject to nearly maximum post-disposal risk (we have not specifically assessed their risk, however) if they maintain lifetime residence in the land area immediately adjacent to the tailings piles. In sum, we believe that the probability of a substantial number of individuals actually incurring these maximum calculated risks is small.

We conclude that it is not reasonable to reduce the emission standard below 20 pCi/m^{2}s because of (1) the uncertainty associated with the feasibility of implementing a requirement for a significantly lower standard, and effectiveness of thicker covers, (2) the small reduction in total health benefit associated with such thicker covers, (3) the limited circumstances in which the maximum risk might be sustained, and (4) the uncertain, but substantial, cost of the added cover thicknesses needed for reasonable assurance of achieving levels that further reduce individual risk significantly.

6.2.3 Impacts of Standards

Environmental Impacts

Under the proposed standards, the tailings would remain covered and isolated for at least 1,000 years. Radon emissions from disposed tailings would be well above normal levels for ordinary land, but well below levels if the tailings were not covered, for thousands of years. Groundwater would be protected for thousands of years under the proposed standards.

The earthen cover material will be obtained from borrow pits close to the tailings pile. For tailings in surface mining locations, the incremental impact of a borrow pit, added to the impact of the surface mining, will be small to negligible. However, in locations where ore is taken from underground mines, the impact of a borrow pit can be significant. The area covered by a borrow pit could range from 16 ha (40 acres) up to 100 ha (250 acres) depending on the depth of the earth that can be removed. Thus, in some cases, the land surface disturbed to obtain cover material could be about the same as the area covered by tailings. In all cases, however, we assumed the topsoil at the borrow pit was saved, all high walls were graded to an 8:1 slope after the earthen cover material was removed, and the topsoil replaced and landscaped.

Health Impacts

The deaths avoided by control of radon are estimated for environmental emissions of radon only, since we can make no reasonable estimate of the potential misuse of tailings. Under these standards, the total deaths avoided (compared to tailings piles which are left uncontrolled) would be about 600 for the first 100 years after disposal and tens of thousands during the expected period of effectiveness of control. These estimates relate to the cumulative generation of tailings projected through the year 2000 and do not take credit for any safety factors introduced into cover design to provide reasonable assurance that the emission and longevity requirements will be satisfied. If no controls are implemented, the health risk to people living very near to tailings (0.5 to 1.0 km from the edge of the tailings pile) is about 2 chances in 100 of fatal lung cancer during their lifetime. This risk is reduced to less than 1 chance in 1,000 under these standards.

The misuse of tailings in constructing buildings poses the greatest hazard to individual health associated with tailings. Under these standards, we believe the probability of unauthorized removal of the tailings will be low for many thousands of years.

We estimate that covering the tailings under the standards could result in about 4 accidental deaths and about 3 radiation-induced deaths for all tailings (existing and new) to the year 2000. These deaths would occur among workers only. These impacts are several orders of magnitude smaller than the estimated benefits of covering the tailings.

Economic Impacts

The economic impacts of the disposal standards are best represented by two cases in our analysis. Economic impact case 7 assumes that all future tailings projected to be generated at existing mills will be disposed of in existing impoundments. Case 31 assumes that all future tailings will be placed in new impoundments with liners. As explained in Chapter 5, these are the two extremes for the industry impacts, with the most likely result falling within these bounds. These two cases assume the same control method for disposal of both existing and new piles, that is, a 2.4 meter earth cover (the top 0.5 meters of which consists of pebbly soil) with rock cover on the 5:1 slopes.

Table 6.1 summarizes the cost and economic impacts of each of these economic impact cases. Based on these estimates, we conclude that compliance with the standards, assuming that other regulatory requirements did not exist, would cost the uranium milling industry from about 310 to 540 million dollars to dispose of all tailings which exist today at licensed sites and those which we estimate to be generated by the year 2000. These costs are present worth estimates (discounted at a 10 percent rate) expressed on a 1983 constant dollar basis.

We estimate that the average uranium price may increase from 2 to 7 percent. As explained in Chapter 5, this range in price increase is determined by the increases in production costs due to tailings disposal estimated for the least impacted model existing mill and the model new mill. In light of the currently poor economic condition of the industry and the threat of foreign competition, it is unlikely that mills will be able to pass through substantial portions of the disposal costs to their customers. The results of our mill closure analysis indicate that under the conditions of no cost pass-through and a medium cash-flow assumption, (20 percent of revenues over the remaining life of the mill), there will be no closures for either Case 7 or 31. When a less favorable cash-flow assumption is used (15 percent), we estimate that one small model mill will close in both cases. Under this same cash-flow assumption (15 percent), the closure in Case 7 will be avoided if there is a $1 per pound of U_3O_8 pass-through, while the closure in Case 31 will be avoided with a $2 per pound pass-through.

These estimates were made by assuming the baseline projection of industry average uranium prices derived from DOE estimates presented in Appendix B. This price projection is an average of two extreme scenarios provided by DOE. We alternatively performed the mill closure analysis for these two impact cases (7 and 31) by using the lower DOE price forecast. Under the conditions of no pass-through and a medium cash-flow margin, there were still no closures estimated. We then tried an even lower price projection - 10 percent lower than DOE's low price projection for every year after 1985 - and the results still showed no closures for Case 7, but one small model mill closure for Case 31.

All of the estimates described above assumed the control costs for both existing and future tailings. As discussed in Chapter 5, if the disposal costs for existing tailings are viewed as a fixed cost of production, then the decision to continue operating in the future may be based on the incremental cost of future tailings disposal only. We, therefore, performed the mill closure analysis again by only including the cost of future tailings disposal. For a variety of cash-flow assumptions and no pass-through, the results also indicated no closures for either economic impact case.

We do not expect any macroeconomic impacts, including foreign trade, to take place as a result of the standards. Since we do not expect any mill closures as a result of this standard, there will be no regional impact on employment.

Table 6.1. Summary of Economic Impacts of Standards

Impact Characteristics	Economic Impact Cases	
	7	31
Present Worth Cost (10^6 1983 dollars)		
Existing Tailings, 10% discount rate	260	260
Existing Tailings, Undiscounted	343	343
Existing Plus Future Tailings, 10% discount rate	314	537
Existing Plus Future Tailings, Undiscounted	508	996
Mill Closures(a)		
100% Cost Absorption, 20% Cash-flow margin	0	0
100% Cost Absorption, 15% Cash-flow margin	1	1
$1/lb Price Pass-through, 15% Cash-flow margin	0	1
$2/lb Price Pass-through, 15% Cash-flow margin	0	0
Uranium Price Increase (percents)(b)		
Model existing mill with lowest increase	2.0	7.2
Model new mill	6.2	6.2

(a) Expressed in small mill equivalents.

(b) Increases in production cost due to tailings disposal, assuming a base production cost (excluding profit) of $30 per pound of U_3O_8.

These costs and economic impacts are not incremental costs of the standards since much of this cost would probably occur in the absence of the standards due to other regulatory requirements. These other requirements are Nuclear Regulatory Commission (NRC) licensing regulations and State regulations, and regulations required under Section 84(a)(1) and (3) of UMTRCA. We did not estimate the costs imposed by these other regulations because that would require a site-specific investigation. Since our standards are required by Congress to be of general application, we decided to develop a generic analysis based on model facilities. Therefore, we could not estimate the net impact of the standards.

Appendix A

Mill Closure Analysis

A.1 Overview

This appendix presents the mill closure analysis. The purpose of the analysis is to assess the economic impact of the proposed standards on individual mills. Industry data on the number of mills in operation and the number and size of existing tailings piles as of January 1983 were used in this analysis. There were 24 mills operating or on standby at this time with tailings piles, plus piles existed at two other licensed mills which ceased operating several years ago.

The mill closure analysis is performed on a model mill basis. Since a preliminary investigation of production cost increases indicates that some mills may be significantly affected by tailings disposal costs under certain control requirements, we have performed a discounted cash flow analysis of several model mills. This analysis relates the control costs to the mill's cash flow to determine if the project is affordable. In this manner, we have assessed the likelihood of each model mill continuing operations while incurring various levels of tailings disposal costs.

A.2 Model Mills

The analysis is performed on a model mill basis. The model mills provide an indication of the degree of economic impact on all mills in the industry by incorporating the major characteristics of various segments of the industry. There are a large number of variables that can differ among actual mills. The models are not intended to provide an exact duplication of any actual or planned mill. The model mills differ according to capacity, remaining life, and size of existing tailings pile.

On the basis of capacity, the model existing mills are segmented into three categories, small, medium, and large, with capacities of 900, 1800, and 3600 metric tons of ore per day, respectively. New mills that may be built are represented by the medium size model mill.

Existing and new mills in the industry may vary considerably in their operating life. For example, some existing mills may be near the end of their operating life, while other existing mills have been operating for more than 20 years and may still have a long remaining operating life. For the model existing mills, the operating lives analyzed are limited to three choices in order to present a manageable number of models, but which are realistic; a model existing mill may have a remaining useful life of five, ten, or fifteen years. A model new mill is assumed to have a useful life of fifteen years. The significance of the remaining life of a mill is that a "short" remaining life permits less time to recover the costs of control than does a "long" remaining life. Also, the remaining life, together with the capacity of the mill and the capacity utilization rate, determines the amount of future tailings that will be generated by an existing mill.

Operating lives of five, ten, and fifteen years are chosen for several reasons. First, although some mills may have operating lives of less than five years or more than fifteen years, most existing mills should be within this range. Second, any existing mill with a remaining useful life of considerably less than five years is likely to experience a significant economic impact. Third, the difference between five years and fifteen years is sufficiently large to indicate differential control cost impacts based on remaining useful life. For economic reasons, a typical new mill is expected to have an operating life of approximately fifteen years, or longer (NRC80, EMJ79). Finally, it is difficult to determine precisely the life of a mill due to changing market conditions, the discovery of new ore deposits, changing technology, and so on. Therefore, five, ten, and fifteen year lives are believed to be reasonable.

The size of actual existing tailings piles varies considerably. Existing tailings piles are represented in the models by one of three tailings pile size categories: two million metric tons, seven million metric tons, or twenty-two million metric tons. A new model mill is projected to produce a tailings pile of 8.4 million metric tons over a fifteen year operating life.

Based on these differential model mill characteristics, there are 27 (3x3x3) possible model existing mills to be analyzed. After examining the characteristics of the 24 mills which were either operating or on standby (as of January 1983), we placed each of them in one of 16 model mill categories. Table A.1 shows a generalized matrix of the three model mill variables (capacity, remaining life, tailings pile size) and the number of licensed mills that fit into each category. Tables A.2, A.3, and A.4 show the categorization of these mills according to capacity, tailings pile size, and remaining life.

Estimates of the remaining lives of mills had to be judgmentally determined since it is highly uncertain how long mills will continue to operate. Each of the regulatory agencies which license the mills was contacted and asked their opinion about the remaining life of each mill that they license. The response from these regulatory agencies indicated that virtually all the existing mills, including the ones on standby, had at least five years of production remaining while many of the mills had fifteen years or greater remaining. These estimates were supplemented, where possible, on information contained in corporate annual reports, Securities and Exchange Commission 10-K Reports, the DOE Commingled Uranium Mill Tailings Study (DOE82), or articles in trade journals. Even though there is presently a great deal of consolidation in mill ownership taking place, the mill and the surrounding ore deposits have an economic life remaining regardless of which company operates the mill.

Table A.1. Generalized Matrix of Existing Mills[a]

Mill Capacity (MT ore/day)	Remaining Life	Tailings Pile Size (10^6 MT)			Total Existing Mills By Capacity
		2	7	22	
900	5 years	1	1		
	10 years	1	3		
	15 years	2			8
1,800	5 years				
	10 years	2	4		
	15 years	2	1		9
3,600	5 years		1	1	
	10 years		1	1	
	15 years	1	1	1	7
	Total Existing Mills By Tailings Pile Size	9	12	3	24

[a] As of January 1983. Excludes two licensed mills with 2 million MT tailings piles that were no longer operating (Edgemont, South Dakota, and Ray Point, Texas) and one licensed mill which has never operated (Marquez, New Mexico).

Source: Tables A.2, A.3, and A.4.

Table A.2. Existing Mills by Capacity[a]
(Metric Tons of Ore Per Day)

900 MT		1,800 MT		3,600 MT	
Size	Company	Size	Company	Size	Company
1,100	Cotter	1,500	Sohio-Reserve	2,700	UNC (Church Rock)
1,200	Union Carbide (Uravan)	2,300	Chevron	5,400	Anaconda
700	Rio Algom	1,800	Energy Fuels Nuclear	6,300	Kerr-McGee
1,300	Atlas	1,800	Western Nuclear (Wellpinit)	3,100	Homestake
700	Plateau Resources	2,300	Pathfinder (Gas Hills)	3,100	Conoco-Pioneer
400	Dawn	1,800	Rocky Mtn. Energy	2,900	Exxon (Powder River)
900	Federal-American	1,500	Western Nuclear (Jeffrey City)	2,700	Minerals Exploration
1,300	Union Carbide (Gas Hills)	1,600	Pathfinder (Shirley Basin)		
		1,400	Petrotomics		
8 Mills		9 Mills		7 Mills	

[a] As of January 1983. Excludes two licensed mills (Edgemont, South Dakota, and Ray Point, Texas) that were no longer operating and one licensed mill (Marquez, New Mexico) which has never operated.

Source: Table 2.10.

Table A.3. Existing Mills by Tailings Pile Size(a)
(Millions of Metric Tons)

2		7		22	
Tailings Pile	Company	Tailings Pile	Company	Tailings Pile	Company
1.7	Cotter	9.0	Union Carbide (Uravan)	20.7	Anaconda
1.9	Sohio-Reserve	8.0	Conoco-Pioneer	27.6	Kerr-McGee
3.2	UNC (Church Rock)	9.3	Atlas	19.2	Homestake
3.3	Chevron	5.4	Federal-American		
2.3	Rio Algom	8.6	Pathfinder (Gas Hills)		
2.9	Dawn	4.5	Rocky Mtn. Energy		
2.3	Western Nuclear (Wellpinit)	6.5	Exxon (Powder River)		
1.1	Energy Fuels Nuclear	7.0	Western Nuclear (Jeffrey City)		
0.0	Plateau Resources	6.5	Union Carbide (Gas Hills)		
		5.3	Pathfinder (Shirley Basin)		
		5.0	Petrotomics		
		10.9	Minerals Exploration		
9 Mills		12 Mills		3 Mills	

(a) As of January 1983. Excludes two licensed mills with 2 million MT tailings piles (Edgemont, South Dakota, and Ray Point, Texas) which were no longer operating and one licensed mill (Marquez, New Mexico) which has never operated.

Source: Table 2.10.

Table A.4. Existing Mills by Estimated Remaining Life[a]

5 Years	10 Years	15 Years
Union Carbide (Gas Hills)	Union Carbide (Uravan)	Cotter Corp.
Anaconda	Conoco-Pioneer	Sohio-Reserve
Dawn	Homestake	UNC (Church Rock)
Exxon (Powder River)	Western Nuclear (Wellpinit)	Kerr-McGee
	Chevron	Energy Fuels Nuclear
	Rio Algom	Plateau Resources
	Rocky Mountain Energy	Western Nuclear (Jeffrey City)
	Atlas	Minerals Exploration
	Federal-American	
	Pathfinder (Gas Hills)	
	Pathfinder (Shirley Basin)	
	Petrotomics	
4 Mills	12 Mills	8 Mills

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[a] As of January 1983. Excludes two licensed mills (Edgemont, South Dakota, and Ray Point, Texas) which were no longer operating and one licensed mill (Marquez, New Mexico) which has never operated.

A.3 Control Costs

The control costs for this analysis are the costs of disposing of the mill tailings. The detailed development of the model pile disposal costs has been explained in Appendix B of the FEIS and will not be repeated here. There are three major categories of control costs. The first category is the cost to control existing tailings piles. The second category is the cost to control future tailings that an existing mill will generate during the remaining life of the operation. The third category is the cost to control tailings generated by a new mill. The cost to control an existing tailings pile is shown in Table A.5 for each economic impact case and model pile size.

Table A.6 shows for each impact case the unit cost and the total cost for a model existing mill to control future tailings. The cost to control future tailings is calculated by multiplying the cost of control per metric ton of tailings by the tons of tailings the model mill will generate during the remaining years of its assigned operating life. The future generation of tailings is a function of the mill's capacity and its capacity utilization rate (discussed in Section A.6).

Additional tailings that are generated by an existing mill can be controlled in one of two major ways, with different costs associated with each. First, future tailings can be added to existing piles, and therefore, both can be controlled in the same manner. This is assumed in impact cases 1 through 13. Second, future tailings can be controlled in the same manner as tailings generated by a new mill and would require a new pile to be started. This is assumed in impact cases 26 through 37.

The unit cost assumed for cases 1 through 13 is the appropriate incremental cost of disposal of tailings which have been added to existing piles. These incremental unit costs have been estimated from the model existing pile disposal costs. The unit cost for Cases 26 through 37 is the average unit cost calculated from the model new pile disposal cost for the appropriate disposal method. The derivation of both of these types of unit costs is presented in Chapter 5.

Table A.7 shows the cost of control for the model new mill. The model new mill has a useful life of fifteen years and generates 8.4 million metric tons of tails.

Tables A.8a, A.8b, and A.8c show the combined control costs to control an existing tailings pile at a model mill, plus the control costs for future tailings generated during the remaining life of the operation. In actuality, no small or medium-sized mills have a tailings pile in the 22 million metric ton category. Therefore, no control costs are shown for a 22 million metric ton tailings pile at a small or medium-sized model mill.

Table A.5. Control Costs for Model Existing Tailings PIles (Millions of 1983 Dollars)

Economic Impact Case	Tailings Pile Size		
	2 (10^6 MT)	7 (10^6 MT)	22 (10^6 MT)
1	-	-	-
2, 26	4.2	6.4	10.8
3, 27	6.9	10.4	17.3
4, 28	9.2	14.0	23.0
5, 29	3.2	6.3	13.6
6, 10, 30, 34	5.9	10.5	20.6
7, 11, 31, 35	8.3	14.3	26.8
8, 12, 33, 36	10.9	18.5	33.8
9, 13, 33, 37	13.3	22.2	40.0

Table A.6.a. Cost to Control Future Tailings at a Small Model Existing Mill
(Millions of 1983 Dollars)

Economic Impact Case	2(a)						7(a)					
	1.0(b)		2.2(b)		3.5(b)		1.0(b)		2.2(b)		3.5(b)	
	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS
1	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
2	0.09	0.1	0.09	0.2	0.09	0.3	0.09	0.1	0.09	0.2	0.09	0.3
3	0.12	0.1	0.12	0.3	0.12	0.4	0.13	0.1	0.13	0.3	0.13	0.5
4	0.16	0.2	0.16	0.4	0.16	0.6	0.15	0.2	0.15	0.3	0.15	0.5
5	0.47	0.5	0.47	1.1	0.47	1.6	0.39	0.4	0.39	0.9	0.39	1.4
6	0.54	0.6	0.54	1.2	0.54	1.9	0.44	0.5	0.44	1.0	0.44	1.5
7	0.60	0.6	0.60	1.3	0.60	2.1	0.49	0.5	0.49	1.1	0.49	1.7
8	0.68	0.7	0.68	1.5	0.68	2.4	0.53	0.6	0.53	1.2	0.53	1.8
9	0.75	0.8	0.75	1.7	0.75	2.6	0.59	0.6	0.59	1.3	0.59	2.1
10	0.54	0.6	0.54	1.2	0.54	1.9	0.44	0.5	0.44	1.0	0.44	1.5
11	0.60	0.6	0.60	1.3	0.60	2.1	0.49	0.5	0.49	1.1	0.49	1.7
12	0.68	0.7	0.68	1.5	0.68	2.4	0.53	0.6	0.53	1.2	0.53	1.8
13	0.75	0.8	0.75	1.7	0.75	2.6	0.59	0.6	0.59	1.3	0.59	2.1

(a) Size of existing tailings pile, million MT.

(b) Future generation of tailings, million MT.

Table A.6.b. Cost to Control Future Tailings at a Medium Model Existing Mill
(Millions of 1983 Dollars)

Economic Impact Case	2(a)						7(a)					
	2.1(b)		4.5(b)		7.0(b)		2.1(b)		4.5(b)		7.0(b)	
	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS
1	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
2	0.09	0.2	0.09	0.4	0.09	0.6	0.09	0.2	0.09	0.4	0.09	0.6
3	0.12	0.2	0.12	0.5	0.12	0.8	0.13	0.3	0.13	0.6	0.13	0.9
4	0.16	0.3	0.16	0.7	0.16	1.1	0.15	0.3	0.15	0.7	0.15	1.0
5	0.47	1.0	0.47	2.1	0.47	3.3	0.39	0.8	0.39	1.8	0.39	2.7
6	0.54	1.1	0.54	2.4	0.54	3.8	0.44	0.9	0.44	2.0	0.44	3.1
7	0.60	1.2	0.60	2.7	0.60	4.2	0.49	1.0	0.49	2.2	0.49	3.4
8	0.68	1.4	0.68	3.1	0.68	4.7	0.53	1.1	0.53	2.4	0.53	3.7
9	0.75	1.6	0.75	3.4	0.75	5.2	0.59	1.2	0.59	2.6	0.59	4.1
10	0.54	1.1	0.54	2.4	0.54	3.8	0.44	0.9	0.44	2.0	0.44	3.1
11	0.60	1.2	0.60	2.7	0.60	4.2	0.49	1.0	0.49	2.2	0.49	3.4
12	0.68	1.4	0.68	3.1	0.68	4.7	0.53	1.1	0.53	2.4	0.53	3.7
13	0.75	1.6	0.75	3.4	0.75	5.2	0.59	1.2	0.59	2.6	0.59	4.1

(a) Size of existing tailings pile, million MT.

(b) Future generation of tailings, million MT.

Table A.6.c. Cost to Control Future Tailings at a Large Model Existing Mill
(Millions of 1983 Dollars)

Economic Impact Case	2[a]						7[a]						22[a]					
	4.2[b]		9.0[b]		13.9[b]		4.2[b]		9.0[b]		13.9[b]		4.2[b]		9.0[b]		13.9[b]	
	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS
1	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0	0.00	0.0
2	0.09	0.4	0.09	0.8	0.09	1.3	0.09	0.4	0.09	0.8	0.09	1.3	0.11	0.5	0.11	1.0	0.11	1.5
3	0.12	0.5	0.12	1.1	0.12	1.7	0.13	0.5	0.13	1.2	0.13	1.8	0.12	0.5	0.12	1.1	0.12	1.7
4	0.16	0.7	0.16	1.4	0.16	2.2	0.15	0.6	0.15	1.3	0.15	2.1	0.11	0.5	0.11	1.0	0.11	1.5
5	0.47	2.0	0.47	4.2	0.47	6.5	0.39	1.6	0.39	3.5	0.39	5.4	0.17	0.7	0.17	1.5	0.17	2.4
6	0.54	2.2	0.54	4.8	0.54	7.5	0.44	1.8	0.44	3.9	0.44	6.1	0.17	0.7	0.17	1.5	0.17	2.4
7	0.60	2.5	0.60	5.4	0.60	8.4	0.49	2.0	0.49	4.4	0.49	6.8	0.18	0.7	0.18	1.6	0.18	2.5
8	0.68	2.8	0.68	6.1	0.68	9.5	0.53	2.2	0.53	4.8	0.53	7.4	0.22	0.9	0.22	2.0	0.22	3.1
9	0.75	3.1	0.75	6.7	0.75	10.4	0.59	2.5	0.59	5.3	0.59	8.2	0.22	0.9	0.22	2.0	0.22	3.1
10	0.54	2.2	0.54	4.8	0.54	7.5	0.44	1.8	0.44	3.9	0.44	6.1	0.17	0.7	0.17	1.5	0.17	2.4
11	0.60	2.5	0.60	5.4	0.60	8.4	0.49	2.0	0.49	4.4	0.49	6.8	0.18	0.7	0.18	1.6	0.18	2.5
12	0.68	2.8	0.68	6.1	0.68	9.5	0.53	2.2	0.53	4.8	0.53	7.4	0.22	0.9	0.22	2.0	0.22	3.1
13	0.75	3.1	0.75	6.7	0.75	10.4	0.59	2.5	0.59	5.3	0.59	8.2	0.22	0.9	0.22	2.0	0.22	3.1

(a) Size of existing tailings pile, million MT.

(b) Future generation of tailings, million MT.

Table A.6.d. Cost to Control Future Tailings at Existing Mills - Starting New Piles
(Millions of 1983 Dollars)

Economic Impact Case	Small Mill						Medium Mill						Large Mill					
	1.0(a)		2.2(a)		3.5(a)		2.1(a)		4.5(a)		7.0(a)		4.2(a)		9.0(a)		13.9(a)	
	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS	$/MT	5 YRS	$/MT	10 YRS	$/MT	15 YRS
26	2.73	2.8	2.73	6.1	2.73	9.5	2.73	5.7	2.73	12.2	2.73	19.0	2.73	11.3	2.73	24.5	2.73	38.0
27	3.15	3.3	3.15	7.1	3.15	11.0	3.15	6.6	3.15	14.2	3.15	22.0	3.15	13.1	3.15	28.3	3.15	43.9
28	3.63	3.8	3.63	8.1	3.63	12.6	3.63	7.5	3.63	16.3	3.63	25.3	3.63	15.1	3.63	32.6	3.63	50.6
29	2.73	2.8	2.73	6.1	2.73	9.5	2.73	5.7	2.73	12.2	2.73	19.0	2.73	11.3	2.73	24.5	2.73	38.0
30	3.27	3.4	3.27	7.3	3.27	11.4	3.27	6.8	3.27	14.7	3.27	22.8	3.27	13.6	3.27	29.4	3.27	45.6
31	3.75	3.9	3.75	8.4	3.75	13.1	3.75	7.8	3.75	16.8	3.75	26.1	3.75	15.6	3.75	33.7	3.75	52.2
32	4.26	4.4	4.26	9.6	4.26	14.8	4.26	8.9	4.26	19.1	4.26	29.7	4.26	17.7	4.26	38.3	4.26	59.4
33	4.75	4.9	4.75	10.7	4.75	16.5	4.75	9.9	4.75	21.3	4.75	33.1	4.75	19.8	4.75	42.6	4.75	66.1
34	4.81	5.0	4.81	10.8	4.81	16.7	4.81	10.0	4.81	21.6	4.81	33.5	4.81	20.0	4.81	43.2	4.81	67.0
35	5.19	5.4	5.19	11.6	5.19	18.1	5.19	10.8	5.19	23.3	5.19	36.1	5.19	21.6	5.19	46.6	5.19	72.3
36	5.67	5.9	5.67	12.7	5.67	19.7	5.67	11.8	5.67	25.4	5.67	39.5	5.67	23.6	5.67	50.9	5.67	78.9
37	6.10	6.3	6.10	13.7	6.10	21.2	6.10	12.7	6.10	27.4	6.10	42.4	6.10	25.3	6.10	54.7	6.10	84.9

(a) Future generation of tailings, million MT.

Table A.7. Control Costs for a Model New Tailings Pile
(Millions of 1983 Dollars)

Economic Impact Case	Tailings Pile Size 8.4 (x 10^6 MT)
1	1.3
2, 26	22.9
3, 27	26.5
4, 28	30.5
5, 29	22.9
6, 30	27.5
7, 31	31.5
8, 32	35.8
9, 33	39.9
10, 34	40.4
11, 35	43.6
12, 36	47.6
13, 37	51.2

Table A.8.a. Total Disposal Cost for a Small Model Existing Mill (Existing Tails plus New Tails in Millions of 1983 Dollars)

Economic Impact Case	2(a)			7(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0
2	4.3	4.4	4.5	6.5	6.6	6.7
3	7.0	7.2	7.3	10.5	10.7	10.9
4	9.4	9.6	9.8	14.2	14.3	14.5
5	3.7	4.3	4.8	6.7	7.2	7.7
6	6.5	7.1	7.8	11.0	11.5	12.0
7	8.9	9.6	10.4	14.8	15.4	16.0
8	11.6	12.4	13.3	19.1	19.7	20.3
9	14.1	15.0	15.9	22.8	23.5	24.3
10	6.5	7.1	7.8	11.0	11.5	12.0
11	8.9	9.6	10.4	14.8	15.4	16.0
12	11.6	12.4	13.3	19.1	19.7	20.3
13	14.1	15.0	15.9	22.8	23.5	24.3
26	7.0	10.3	13.7	9.2	12.5	15.9
27	10.2	14.0	17.9	13.7	17.5	21.4
28	13.0	17.3	21.8	17.8	22.1	26.6
29	6.0	9.3	12.7	9.1	12.4	15.8
30	9.3	13.2	17.3	13.9	17.8	21.9
31	12.2	16.7	21.4	18.2	22.7	27.4
32	15.3	20.5	25.7	22.9	28.1	33.3
33	18.2	24.0	29.8	27.1	32.9	38.7
34	10.9	16.7	22.6	15.5	21.3	27.2
35	13.7	19.9	26.4	19.7	25.9	32.4
36	16.8	23.6	30.6	24.4	31.2	38.2
37	19.6	27.0	34.5	28.5	35.9	43.4

(a) Size of existing tailings pile, million MT.

Table A.8.b. Total Disposal Cost for a Medium Model Existing Mill (Existing Tails Plus New Tails in Millions of 1983 Dollars)

Economic Impact Case	2(a)			7(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0
2	4.4	4.6	4.8	6.6	6.8	7.0
3	7.1	7.4	7.7	10.7	11.0	11.3
4	9.5	9.9	10.3	14.3	14.7	15.0
5	4.2	5.3	6.5	7.1	8.1	9.0
6	7.0	8.3	9.7	11.4	12.5	13.6
7	9.5	11.0	12.5	15.3	16.5	17.7
8	12.3	14.0	15.6	19.6	20.9	22.2
9	14.9	16.7	18.5	23.4	24.8	26.3
10	7.0	8.3	9.7	11.4	12.5	13.6
11	9.5	11.0	12.5	15.3	16.5	17.7
12	12.3	14.0	15.6	19.6	20.9	22.2
13	14.9	16.7	18.5	23.4	24.8	26.3
26	9.9	16.4	23.2	12.1	18.6	25.4
27	13.5	21.1	28.9	17.0	24.6	32.4
28	16.7	25.5	34.5	21.5	30.3	39.3
29	8.9	15.4	22.2	12.0	18.5	25.3
30	12.7	20.6	28.7	17.3	25.2	33.3
31	16.1	25.1	34.4	22.1	31.1	40.4
32	19.8	30.0	40.6	27.4	37.6	48.2
33	23.2	34.6	46.4	32.1	43.5	55.3
34	15.9	27.5	39.4	20.5	32.1	44.0
35	19.1	31.6	44.4	25.1	37.6	50.4
36	22.7	36.3	50.4	30.3	43.9	58.0
37	26.0	40.7	55.7	34.9	49.6	64.6

(a) Size of existing tailings pile, million MT.

Table A.8.c. Total Disposal Cost for a Large Model Existing Mill (Existing Tails Plus New Tails in Millions of 1983 Dollars)

Economic Impact Case	2(a)			7(a)			22(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	4.6	5.0	5.5	6.8	7.2	7.7	11.3	11.8	12.3
3	7.4	8.0	8.6	10.9	11.6	12.2	17.8	18.4	19.0
4	9.9	10.6	11.4	14.6	15.3	16.1	23.5	24.0	24.5
5	5.2	7.4	9.7	7.9	9.8	11.7	14.3	15.1	16.0
6	8.1	10.7	13.4	12.3	14.4	16.6	21.3	22.1	23.0
7	10.8	13.7	16.7	16.3	18.7	21.1	27.5	28.4	29.3
8	13.7	17.0	20.4	20.7	23.3	25.9	34.7	35.8	36.9
9	16.4	20.0	23.7	24.7	27.5	30.4	40.9	42.0	43.1
10	8.1	10.7	13.4	12.3	14.4	16.6	21.3	22.1	23.0
11	10.8	13.7	16.7	16.3	18.7	21.1	27.5	28.4	29.3
12	13.7	17.0	20.4	20.7	23.3	25.9	34.7	35.8	36.9
13	16.4	20.0	23.7	24.7	27.5	30.4	40.9	42.0	43.1
26	15.5	28.7	42.2	17.7	30.9	44.4	22.1	35.3	48.8
27	20.0	35.2	50.8	23.5	38.7	54.3	30.4	45.6	61.2
28	24.3	41.8	59.8	29.1	46.6	64.6	38.1	55.6	73.6
29	14.5	27.7	41.2	17.6	30.8	44.3	24.9	38.1	51.6
30	19.5	35.3	51.5	24.1	39.9	56.1	34.2	50.0	66.2
31	23.9	42.0	60.5	29.9	48.0	66.5	42.4	60.5	79.0
32	28.6	49.2	70.3	36.2	56.8	77.9	51.5	72.1	93.2
33	33.1	55.9	79.4	42.0	64.8	88.3	59.8	82.6	106.1
34	25.9	49.1	72.9	30.5	53.7	77.5	40.6	63.8	87.6
35	29.9	54.9	80.6	35.9	60.9	86.6	48.4	73.4	99.1
36	34.5	61.8	89.8	42.1	69.4	97.4	57.4	84.7	112.7
37	38.6	68.0	98.2	47.5	76.9	107.1	65.3	94.7	124.9

(a) Size of existing tailings pile, million MT.

A.4 Production Cost Increases

One way to gain a perspective on the degree of impact that the control costs may have on the model mills is to calculate the percentage change in production costs due to tailings disposal. This relatively simple estimation will provide an indication of both how significant the costs are and how the impacts vary by model mill. Table A.9.a shows the control cost increase for the small existing mill expressed as dollars per metric ton of ore milled (assuming a remaining life of 5 years, 10 years, or 15 years). This unit control cost is derived by dividing the total costs shown on Table A.8.a by the approximate number of metric tons of future production as shown on Table A.9.a. Table A.9.b expresses this cost increase in terms of dollars per pound of U_3O_8 produced. Assuming an average ore grade of .1 percent and a recovery rate of 93 percent, one metric ton of ore yields about two pounds of U_3O_8. Therefore, the cost per metric ton of ore divided by two equals the cost per pound of U_3O_8. Finally, Table A.9.c shows the percentage increase in production cost assuming a base production cost (excluding profit) of $30 per pound of U_3O_8. For the lack of company-specific cost data, we have assumed that the $30 per pound production cost applies uniformly to all mills. Tables A.10 (a,b,c) and A.11 (a,b,c) present the same type of information for the medium and large existing mills. Table A.12 presents the same information for the model new mill.

Upon examining the estimated production cost increases, it is evident that for some economic impact cases the increases are substantial. Also, some of the model mills are affected significantly more than others. Because the control costs may be significant, we conclude that a plant closure analysis is necessary to determine the economic impact on the mills since it is unlikely that they can pass-through a large part of the control cost to their customers.

A.5 Discounted Cash Flow Analysis

The impact of the control costs on the model mills can be assessed using the discounted cash flow (DCF) technique. DCF is a financial analysis technique that indicates if a project is justified on economic grounds. Among financial analysis techniques, DCF is the most comprehensive due to two principal advantages over most other financial analysis techniques. First, DCF considers the time value of money. Second, DCF considers the cash flow items that are applicable to a project, rather than just the earnings applicable to a project. Other than earnings, the principal cash flow items are depreciation and depletion. Although depreciation and depletion are legal business expenses for income tax purposes, they do not represent actual cash expenses for the firm for the year. Therefore, in order to calculate cash flows, depreciation and depletion are added to earnings.

Table A.9.a. Production Cost Increases for a Small Model Existing Mill, $/Metric Ton of Ore

Economic Impact Case	2(a)			7(a)		
	1.0(b) 5 YRS	2.2(b) 10 YRS	3.5(b) 15 YRS	1.0(b) 5 YRS	2.2(b) 10 YRS	3.5(b) 15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00
2	4.13	1.96	1.30	6.25	2.94	1.93
3	6.76	3.19	2.10	10.13	4.76	3.12
4	9.01	4.26	2.80	13.62	6.39	4.17
5	3.55	1.90	1.39	6.45	3.20	2.20
6	6.22	3.17	2.23	10.54	5.12	3.46
7	8.58	4.30	2.98	14.25	6.86	4.60
8	11.17	5.54	3.81	18.33	8.77	5.84
9	13.54	6.68	4.57	21.95	10.48	6.97
10	6.22	3.17	2.23	10.54	5.12	3.46
11	8.58	4.30	2.98	14.25	6.86	4.60
12	11.17	5.54	3.81	18.33	8.77	5.84
13	13.54	6.68	4.57	21.95	10.48	6.97
26	6.77	4.60	3.93	8.88	5.58	4.56
27	9.79	6.23	5.14	13.16	7.79	6.14
28	12.48	7.73	6.27	17.10	9.87	7.65
29	5.80	4.15	3.65	8.79	5.53	4.54
30	8.95	5.90	4.97	13.37	7.95	6.29
31	11.73	7.45	6.13	17.51	10.12	7.86
32	14.75	9.12	7.39	22.06	12.51	9.58
33	17.54	10.68	8.57	26.11	14.64	11.13
34	10.49	7.44	6.50	14.91	9.49	7.83
35	13.18	8.89	7.57	18.95	11.56	9.30
36	16.15	10.52	8.80	23.46	13.91	10.98
37	18.89	12.02	9.92	27.45	15.99	12.47

(a) Size of existing tailings pile, million MT.

(b) Future production of uranium, million MT of ore.

Table A.9.b. Production Cost Increases for a Small Model Existing Mill, $/Pound of U_3O_8

Economic Impact Case	2[a]			7[a]		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00
2	2.07	0.98	0.65	3.12	1.47	0.96
3	3.38	1.60	1.05	5.07	2.38	1.56
4	4.51	2.13	1.40	6.81	3.19	2.09
5	1.77	0.95	0.69	3.23	1.60	1.10
6	3.11	1.58	1.12	5.27	2.56	1.73
7	4.29	2.15	1.49	7.12	3.43	2.30
8	5.58	2.77	1.91	9.16	4.39	2.92
9	6.77	3.34	2.29	10.97	5.24	3.48
10	3.11	1.58	1.12	5.27	2.56	1.73
11	4.29	2.15	1.49	7.12	3.43	2.30
12	5.58	2.77	1.91	9.16	4.39	2.92
13	6.77	3.34	2.29	10.97	5.24	3.48
26	3.38	2.30	1.97	4.44	2.79	2.28
27	4.90	3.11	2.57	6.58	3.89	3.07
28	6.24	3.87	3.14	8.55	4.93	3.83
29	2.90	2.08	1.82	4.39	2.77	2.27
30	4.47	2.95	2.48	6.69	3.98	3.14
31	5.87	3.72	3.07	8.75	5.06	3.93
32	7.37	4.56	3.70	11.03	6.25	4.79
33	8.77	5.34	4.29	13.05	7.32	5.56
34	5.24	3.72	3.25	7.46	4.74	3.91
35	6.59	4.44	3.79	9.47	5.78	4.65
36	8.08	5.26	4.40	11.73	6.96	5.49
37	9.44	6.01	4.96	13.73	7.99	6.24

[a] Size of existing tailings pile, million MT.

Table A.9.c. Production Cost Increases for a Small Model Existing Mill, Percentage Increase[a]

Economic Impact Case	2[b]			7[b]		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0
2	6.9	3.3	2.2	10.4	4.9	3.2
3	11.3	5.3	3.5	16.9	7.9	5.2
4	15.0	7.1	4.7	22.7	10.6	7.0
5	5.9	3.2	2.3	10.8	5.3	3.7
6	10.4	5.3	3.7	17.6	8.5	5.8
7	14.3	7.2	5.0	23.7	11.4	7.7
8	18.6	9.2	6.4	30.5	14.6	9.7
9	22.6	11.1	7.6	36.6	17.5	11.6
10	10.4	5.3	3.7	17.6	8.5	5.8
11	14.3	7.2	5.0	23.7	11.4	7.7
12	18.6	9.2	6.4	30.5	14.6	9.7
13	22.6	11.1	7.6	36.6	17.5	11.6
26	11.3	7.7	6.6	14.8	9.3	7.6
27	16.3	10.4	8.6	21.9	13.0	10.2
28	20.8	12.9	10.5	28.5	16.4	12.8
29	9.7	6.9	6.1	14.6	9.2	7.6
30	14.9	9.8	8.3	22.3	13.3	10.5
31	19.6	12.4	10.2	29.2	16.9	13.1
32	24.6	15.2	12.3	36.8	20.8	16.0
33	29.2	17.8	14.3	43.5	24.4	18.5
34	17.5	12.4	10.8	24.9	15.8	13.0
35	22.0	14.8	12.6	31.6	19.3	15.5
36	26.9	17.5	14.7	39.1	23.2	18.3
37	31.5	20.0	16.5	45.8	26.6	20.8

[a] Assumes a base production cost (excluding profit) of $30 per pound of U_3O_8.

[b] Size of existing tailings pile, million MT.

Table A.10.a. Production Cost Increases for a Medium Model Existing Mill
$/Metric Ton of Ore

Economic Impact Case	2(a)			7(a)		
	2.1(b) 5 YRS	4.5(b) 10 YRS	7.0(b) 15 YRS	2.1(b) 5 YRS	4.5(b) 10 YRS	7.0(b) 15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00
2	2.11	1.03	0.69	3.17	1.52	1.01
3	3.44	1.66	1.11	5.13	2.45	1.62
4	4.59	2.21	1.48	6.88	3.27	2.16
5	2.01	1.18	0.93	3.42	1.79	1.29
6	3.38	1.85	1.39	5.49	2.78	1.95
7	4.59	2.45	1.79	7.37	3.68	2.54
8	5.92	3.11	2.25	9.43	4.65	3.19
9	7.15	3.71	2.66	11.27	5.54	3.78
10	3.38	1.85	1.39	5.49	2.78	1.95
11	4.59	2.45	1.79	7.37	3.68	2.54
12	5.92	3.11	2.25	9.43	4.65	3.19
13	7.15	3.71	2.66	11.27	5.54	3.78
26	4.75	3.66	3.33	5.80	4.15	3.65
27	6.47	4.69	4.15	8.16	5.47	4.65
28	8.06	5.68	4.95	10.36	6.75	5.64
29	4.27	3.44	3.19	5.76	4.13	3.63
30	6.11	4.59	4.12	8.32	5.61	4.78
31	7.74	5.60	4.94	10.63	6.94	5.80
32	9.50	6.69	5.83	13.16	8.38	6.92
33	11.15	7.71	6.66	15.43	9.70	7.94
34	7.65	6.12	5.66	9.86	7.15	6.32
35	9.18	7.04	6.38	12.07	8.38	7.24
36	10.91	8.10	7.23	14.57	9.79	8.32
37	12.49	9.06	8.01	16.77	11.04	9.28

(a) Size of existing tailings pile, million MT.

(b) Future production of uranium, million MT of ore.

Table A.10.b. Production Cost Increases for a Medium Model Existing Mill
\$/Pound of U_3O_8

Economic Impact Case	2(a)			7(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00
2	1.06	0.51	0.35	1.58	0.76	0.50
3	1.72	0.83	0.56	2.57	1.22	0.81
4	2.29	1.10	0.74	3.44	1.63	1.08
5	1.00	0.59	0.46	1.71	0.90	0.65
6	1.69	0.93	0.69	2.75	1.39	0.97
7	2.30	1.22	0.90	3.68	1.84	1.27
8	2.96	1.55	1.12	4.71	2.33	1.59
9	3.57	1.86	1.33	5.63	2.77	1.89
10	1.69	0.93	0.69	2.75	1.39	0.97
11	2.30	1.22	0.90	3.68	1.84	1.27
12	2.96	1.55	1.12	4.71	2.33	1.59
13	3.57	1.86	1.33	5.63	2.77	1.89
26	2.37	1.83	1.66	2.90	2.08	1.82
27	3.24	2.35	2.07	4.08	2.74	2.32
28	4.03	2.84	2.48	5.18	3.38	2.82
29	2.13	1.72	1.59	2.88	2.06	1.82
30	3.06	2.29	2.06	4.16	2.81	2.39
31	3.87	2.80	2.47	5.31	3.47	2.90
32	4.75	3.35	2.91	6.58	4.19	3.46
33	5.57	3.86	3.33	7.71	4.85	3.97
34	3.82	3.06	2.83	4.93	3.57	3.16
35	4.59	3.52	3.19	6.03	4.19	3.62
36	5.45	4.05	3.62	7.28	4.89	4.16
37	6.25	4.53	4.00	8.39	5.52	4.64

(a) Size of existing tailings pile, million MT.

Table A.10.c. Production Cost Increases for a Medium Model Existing Mill Percentage Increase[a]

Economic Impact Case	2[b]			7[b]		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0
2	3.5	1.7	1.2	5.3	2.5	1.7
3	5.7	2.8	1.9	8.6	4.1	2.7
4	7.6	3.7	2.5	11.5	5.4	3.6
5	3.3	2.0	1.5	5.7	3.0	2.2
6	5.6	3.1	2.3	9.2	4.6	3.2
7	7.7	4.1	3.0	12.3	6.1	4.2
8	9.9	5.2	3.7	15.7	7.8	5.3
9	11.9	6.2	4.4	18.8	9.2	6.3
10	5.6	3.1	2.3	9.2	4.6	3.2
11	7.7	4.1	3.0	12.3	6.1	4.2
12	9.9	5.2	3.7	15.7	7.8	5.3
13	11.9	6.2	4.4	18.8	9.2	6.3
26	7.9	6.1	5.5	9.7	6.9	6.1
27	10.8	7.8	6.9	13.6	9.1	7.7
28	13.4	9.5	8.3	17.3	11.3	9.4
29	7.1	5.7	5.3	9.6	6.9	6.1
30	10.2	7.6	6.9	13.9	9.4	8.0
31	12.9	9.3	8.2	17.7	11.6	9.7
32	15.8	11.2	9.7	21.9	14.0	11.5
33	18.6	12.9	11.1	25.7	16.2	13.2
34	12.7	10.2	9.4	16.4	11.9	10.5
35	15.3	11.7	10.6	20.1	14.0	12.1
36	18.2	13.5	12.1	24.3	16.3	13.9
37	20.8	15.1	13.3	28.0	18.4	15.5

[a] Assumes a base production cost (excluding profit) of $30 per pound of U_3O_8.

[b] Size of existing tailings pile, million MT.

Table A.11.a. Production Cost Increases for a Large Model Existing Mill, $/Metric Ton of Ore

Economic Impact Case	2(a)			7(a)			22(a)		
	4.2(b) 5 YRS	9.0(b) 10 YRS	13.9(b) 15 YRS	4.2(b) 5 YRS	9.0(b) 10 YRS	13.9(b) 15 YRS	4.2(b) 5 YRS	9.0(b) 10 YRS	13.9(b) 15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.10	0.56	0.39	1.63	0.80	0.55	2.71	1.31	0.89
3	1.78	0.89	0.62	2.63	1.29	0.88	4.28	2.05	1.36
4	2.37	1.18	0.82	3.52	1.71	1.16	5.64	2.67	1.76
5	1.24	0.83	0.70	1.91	1.09	0.84	3.44	1.69	1.15
6	1.96	1.20	0.96	2.97	1.61	1.19	5.12	2.47	1.65
7	2.60	1.52	1.20	3.93	2.08	1.52	6.63	3.17	2.10
8	3.30	1.89	1.46	4.98	2.59	1.86	8.35	3.99	2.65
9	3.95	2.23	1.71	5.93	3.06	2.18	9.84	4.68	3.09
10	1.96	1.20	0.96	2.97	1.61	1.19	5.12	2.47	1.65
11	2.60	1.52	1.20	3.93	2.08	1.52	6.63	3.17	2.10
12	3.30	1.89	1.46	4.98	2.59	1.86	8.35	3.99	2.65
13	3.95	2.23	1.71	5.93	3.06	2.18	9.84	4.68	3.09
26	3.74	3.19	3.03	4.27	3.44	3.19	5.32	3.93	3.50
27	4.81	3.92	3.65	5.66	4.31	3.90	7.32	5.08	4.40
28	5.84	4.66	4.29	7.00	5.19	4.64	9.16	6.19	5.28
29	3.50	3.08	2.96	4.24	3.43	3.18	6.00	4.24	3.70
30	4.69	3.93	3.70	5.80	4.44	4.03	8.23	5.57	4.75
31	5.75	4.67	4.35	7.19	5.34	4.78	10.20	6.74	5.67
32	6.88	5.48	5.04	8.71	6.32	5.59	12.39	8.03	6.69
33	7.95	6.23	5.71	10.09	7.22	6.34	14.37	9.21	7.62
34	6.23	5.47	5.23	7.33	5.98	5.56	9.76	7.10	6.29
35	7.19	6.12	5.79	8.63	6.78	6.22	11.64	8.18	7.11
36	8.29	6.88	6.45	10.12	7.73	7.00	13.80	9.43	8.09
37	9.29	7.58	7.05	11.43	8.57	7.69	15.72	10.55	8.97

(a) Size of existing tailings pile, million MT.

(b) Future production of uranium, million MT of ore.

Table A.11.b. Production Cost Increases for a Large Model Existing Mill, \$/Pound of U_3O_8

Economic Impact Case	2[(a)]			7[(a)]			22[(a)]		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.55	0.28	0.20	0.81	0.40	0.27	1.35	0.66	0.44
3	0.89	0.44	0.31	1.32	0.64	0.44	2.14	1.02	0.68
4	1.19	0.59	0.41	1.76	0.85	0.58	2.82	1.34	0.88
5	0.62	0.41	0.35	0.95	0.55	0.42	1.72	0.84	0.57
6	0.98	0.60	0.48	1.48	0.80	0.60	2.56	1.23	0.82
7	1.30	0.76	0.60	1.96	1.04	0.76	3.31	1.58	1.05
8	1.65	0.95	0.73	2.49	1.30	0.93	4.17	1.99	1.32
9	1.97	1.12	0.85	2.96	1.53	1.09	4.92	2.34	1.55
10	0.98	0.60	0.48	1.48	0.80	0.60	2.56	1.23	0.82
11	1.30	0.76	0.60	1.96	1.04	0.76	3.31	1.58	1.05
12	1.65	0.95	0.73	2.49	1.30	0.93	4.17	1.99	1.32
13	1.97	1.12	0.85	2.96	1.53	1.09	4.92	2.34	1.55
26	1.87	1.60	1.51	2.13	1.72	1.59	2.66	1.96	1.75
27	2.41	1.96	1.83	2.83	2.16	1.95	3.66	2.54	2.20
28	2.92	2.33	2.15	3.50	2.60	2.32	4.58	3.10	2.64
29	1.75	1.54	1.48	2.12	1.71	1.59	3.00	2.12	1.85
30	2.35	1.97	1.85	2.90	2.22	2.01	4.11	2.78	2.38
31	2.87	2.34	2.17	3.59	2.67	2.39	5.10	3.37	2.84
32	3.44	2.74	2.52	4.36	3.16	2.80	6.20	4.01	3.34
33	3.97	3.12	2.85	5.04	3.61	3.17	7.19	4.60	3.81
34	3.11	2.73	2.62	3.67	2.99	2.78	4.88	3.55	3.14
35	3.59	3.06	2.89	4.31	3.39	3.11	5.82	4.09	3.56
36	4.14	3.44	3.22	5.06	3.86	3.50	6.90	4.72	4.05
37	4.65	3.79	3.53	5.72	4.28	3.84	7.86	5.28	4.48

(a) Size of existing tailings pile, million MT.

Table A.11.c. Production Cost Increases for a Large Model Existing Mill, Percentage Increase(a)

Economic Impact Case	2(b)			7(b)			22(b)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1.8	0.9	0.7	2.7	1.3	0.9	4.5	2.2	1.5
3	3.0	1.5	1.0	4.4	2.1	1.5	7.1	3.4	2.3
4	4.0	2.0	1.4	5.9	2.8	1.9	9.4	4.5	2.9
5	2.1	1.4	1.2	3.2	1.8	1.4	5.7	2.8	1.9
6	3.3	2.0	1.6	4.9	2.7	2.0	8.5	4.1	2.7
7	4.3	2.5	2.0	6.5	3.5	2.5	11.0	5.3	3.5
8	5.5	3.2	2.4	8.3	4.3	3.1	13.9	6.6	4.4
9	6.6	3.7	2.8	9.9	5.1	3.6	16.4	7.8	5.2
10	3.3	2.0	1.6	4.9	2.7	2.0	8.5	4.1	2.7
11	4.3	2.5	2.0	6.5	3.5	2.5	11.0	5.3	3.5
12	5.5	3.2	2.4	8.3	4.3	3.1	13.9	6.6	4.4
13	6.6	3.7	2.8	9.9	5.1	3.6	16.4	7.8	5.2
26	6.2	5.3	5.0	7.1	5.7	5.3	8.9	6.5	5.8
27	8.0	6.5	6.1	9.4	7.2	6.5	12.2	8.5	7.3
28	9.7	7.8	7.2	11.7	8.7	7.7	15.3	10.3	8.8
29	5.8	5.1	4.9	7.1	5.7	5.3	10.0	7.1	6.2
30	7.8	6.6	6.2	9.7	7.4	6.7	13.7	9.3	7.9
31	9.6	7.8	7.2	12.0	8.9	8.0	17.0	11.2	9.5
32	11.5	9.1	8.4	14.5	10.5	9.3	20.7	13.4	11.1
33	13.2	10.4	9.5	16.8	12.0	10.6	24.0	15.3	12.7
34	10.4	9.1	8.7	12.2	10.0	9.3	16.3	11.8	10.5
35	12.0	10.2	9.6	14.4	11.3	10.4	19.4	13.6	11.9
36	13.8	11.5	10.7	16.9	12.9	11.7	23.0	15.7	13.5
37	15.5	12.6	11.8	19.1	14.3	12.8	26.2	17.6	14.9

(a) Assumes a base production cost (excluding profit) of $30 per pound of U_3O_8.

(b) Size of existing tailings pile, million MT.

Table A.12. Production Cost Increases for a Model New Mill

Economic Impact Case	$/Metric Ton of Ore	$/Pound of U_3O_8	Percentage Price Increase in Production Cost[a]
1	0.15	0.08	0.3
2	2.73	1.36	4.5
3	3.15	1.58	5.3
4	3.63	1.82	6.1
5	2.73	1.36	4.5
6	3.27	1.64	5.5
7	3.75	1.87	6.2
8	4.26	2.13	7.1
9	4.75	2.37	7.9
10	4.81	2.40	8.0
11	5.19	2.60	8.7
12	5.67	2.83	9.4
13	6.10	3.05	10.2
26	2.73	1.36	4.5
27	3.15	1.58	5.3
28	3.63	1.82	6.1
29	2.73	1.36	4.5
30	3.27	1.64	5.5
31	3.75	1.87	6.2
32	4.26	2.13	7.1
33	4.75	2.37	7.9
34	4.81	2.40	8.0
35	5.19	2.60	8.7
36	5.67	2.83	9.4
37	6.10	3.05	10.2

(a) Assumes a base production cost (excluding profit) of $30 per pound of U_3O_8.

DCF is most useful in complex analytical situations, such as when earnings or cash flows are fluctuating significantly, or when several pollution control investments for a single project must be made during different time periods, or when control costs are very high. In situations that involve few variables, or variables that only change slightly, a technique less comprehensive and time-consuming than DCF, such as Return on Investment (ROI), may be sufficient.

The data for the DCF analysis should be as specific as possible to the relevant profit center. This may be difficult in some cases because individual plant data may not be publicly available from multi-plant companies involved in several business segments. Also, in some circumstances, factors that cannot readily be quantified and identified in a DCF analysis may be important. For example, some industries may involve several stages of production, each of which is a separate profit center but which may all be closely related within a single company, such as mining, smelting, and refining. Another possibility is that several products may complement each other and, hence, may be collectively important in order to allow a firm to offer a complete product line to its customers.

The complexity of a DCF analysis and its parameters can be adjusted depending on the data available and the overall rigor necessary for any particular case. The parameters for each year for a typical DCF analysis are presented below in Table A.13. Most of the parameters shown in Table A.13 are self-explanatory. As particular circumstances warrant, the costs parameter can represent total costs, or the costs parameter can be separated into fixed costs and variable costs or separated into more detailed costs such as energy, labor, materials, and so on. Depreciation can be presented using the straight-line method or an accelerated method. Depreciation is typically presented using the straight-line method because it is the easiest method to calculate, and it yields more conservative results than accelerated methods. Depletion is a variable that applies only to extractive types of investments, such as mining and drilling for oil. State taxes is an example of a parameter not shown in Table A.13, but which may be necessary in particular analyses. Some analyses may require a provision for a tax loss carryforward. Normally, investments are financed partially with debt and partially with equity; however, if a particular investment is financed totally with equity, then the interest and principal repayment parameters, which are due to debt, will not be present. The sustaining capital expenditures variable represents expenditures required to maintain the plant in good working condition and maintain salvage value. Rather than include sustaining capital expenditures in an analysis, an alternative assumption that is sometimes used is that salvage value declines to zero due to a lack of sustaining capital expenditures. The conventional practice with respect to the discount rate is to use a discount rate that assumes cash flows occur at a single (discrete) point in time at the end of each year, rather than a discount rate that assumes cash flows occur continuously throughout a year. The variables that are affected by inflation, such as revenue and costs, can be expressed in either real or nominal terms, but the choice must be consistent throughout an analysis for all relevant variables.

Table A.13. Discounted Cash Flow Parameters

1. Revenue
2. Costs
3. Depreciation
4. Interest
5. Control O&M Cost
6. Control Depreciation
7. Control Interest
8. Earnings Before Tax [1 - (2, 3, 4, 5, 6, 7)]
9. Depletion
10. Tax Liability
11. Investment Tax Credit
12. Control Investment Tax Credit
13. Minimum Tax
14. Total Tax Due [(10 - (11 + 12))+ 13]
15. Earnings After Tax [8 - 14]
16. Depreciation
17. Control Depreciation
18. Depletion
19. Cash Flow Before Deduction [15 + 16 + 17 + 18]
20. Principal Payments
21. Control Principal Payments
22. Sustaining Capital Expenditures
23. Net Cash Flow [19 - (20 + 21 + 22)]
24. Discount Factor
25. Discounted Net Cash Flow [23 x 24]

Each annual net cash flow is calculated and then discounted. The discounted net cash flows for all years of a project life are then summed to yield the present value of the cash flows. The initial investment is subtracted from the present value of the cash flows to yield the net present value (NPV). The complete process using simple assumptions for ease of presentation is shown in Table A.14. Several items that are not shown in Table A.14 that may be present in some analyses are salvage value, the recovery of working capital at the end of a project's life, and terminal value. Terminal value is a means of representing any continuing value of a project beyond the years shown in a detailed DCF analysis. For example, Table A.14 presents a ten-year analysis period. If the project illustrated in Table A.14 is expected to continue in operation beyond ten years, terminal value could be used to represent the continuing life of the project.

If the NPV of a project is positive, this means that the project returns more than the firm's cost of capital and the project should be accepted. If the NPV of a project is negative, this means that a project returns less than the firm's cost of capital and the project should be rejected. If the NPV of a project is zero, this means that the project returns exactly the firm's cost of capital and the project should be accepted. However, as a practical matter, there is an element of uncertainty associated with most data and projections. Therefore, for most DCF analyses, and particularly if the NPV is at or near zero, it is desirable to conduct sensitivity analysis. The circumstances of each case will determine which variables are candidates for sensitivity analysis.

There are two methods that can be used in a discounted cash flow analysis: the weighted average cost of capital method (WACC), or the cost of equity method. The basic difference between the two methods centers around whether the discount rate represents the weighted average cost of capital or the cost of equity. The weighted average cost of capital uses a discount rate that represents the combined cost of debt and equity. Because the discount rate for the WACC includes the cost of debt, there are no explicit interest payments. Because the original investment represents both debt and equity, there are no explicit principal payments. In the cost of equity method, the discount rate represents only the cost of equity. Therefore, interest payments on debt are identified explicitly. Also, the original investment represents only the equity share of the original investment, and, as a result, the debt portion of the original investment is considered through regular principal repayments.

The analyst should consider supplementing NPV analysis with other techniques such as ROI, internal rate of return (IRR), payback, and so on. For example, if a given industry normally relies on ROI to make decisions, then an ROI analysis, in addition to a DCF analysis, may be desirable in order to use the same technique that industry uses to make

Table A.14. Discounted Cash Flow Analysis
(Dollars in Thousands)

Financing: 100% Equity

		Year									
		1	2	3	4	5	6	7	8	9	10
1.	Revenue	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
2.	Cost	700	700	700	700	700	700	700	700	700	700
3.	Depreciation	100	100	100	100	100	100	100	100	100	100
4.	Interest	0	0	0	0	0	0	0	0	0	0
5.	Control O&M Cost	0	0	0	0	0	0	0	0	0	0
6.	Control Depreciation	0	0	0	0	0	0	0	0	0	0
7.	Control Interest	0	0	0	0	0	0	0	0	0	0
8.	Earnings Before Tax	200	200	200	200	200	200	200	200	200	200
9.	Depletion	0	0	0	0	0	0	0	0	0	0
10.	Tax Liability	100	100	100	100	100	100	100	100	100	100
11.	Investment Tax Credit	50	50	0	0	0	0	0	0	0	0
12.	Control Investment Tax Credit	0	0	0	0	0	0	0	0	0	0
13.	Minimum Tax	0	0	0	0	0	0	0	0	0	0
14.	Total Tax Due	50	50	100	100	100	100	100	100	100	100
15.	Earnings After Tax	150	150	100	100	100	100	100	100	100	100
16.	Depreciation	100	100	100	100	100	100	100	100	100	100
17.	Control Depreciation	0	0	0	0	0	0	0	0	0	0
18.	Depletion	0	0	0	0	0	0	0	0	0	0
19.	Cash Flow Before Deduction	250	250	200	200	200	200	200	200	200	200
20.	Principal Payments	0	0	0	0	0	0	0	0	0	0
21.	Control Principal Payments	0	0	0	0	0	0	0	0	0	0
22.	Sustaining Capital Expenditures	0	0	0	0	0	0	0	0	0	0
23.	Net Cash Flow	250	250	200	200	200	200	200	200	200	200
24.	Discount Factor	.909	.826	.751	.683	.621	.564	.513	.467	.424	.386
25.	Discounted Net Cash Flow	227.3	206.5	150.2	136.6	124.2	112.8	102.6	93.4	84.8	77.2

Present Value of Cash Flows		1,315.6
Original Investment	-	1,000.0
Net Present Value	+	315.6

decisions. Internal rate of return is an analytical technique similar to NPV. The difference between IRR and NPV is in the discounting of the cash flows. The NPV calculation discounts the cash flows at a predetermined discount rate, whereas IRR seeks that discount rate which yields an NPV equal to zero. After the IRR for an investment project is calculated, the firm's cost of capital is compared to the IRR for the investment project. If the IRR is greater than or equal to the firm's cost of capital, the project should be accepted. If the IRR is less than the firm's cost of capital, the project should be rejected. The payback period is an example of another analytical technique that should be considered as a potential supplement to a DCF analysis. The value of considering payback as a supplement to DCF is that DCF does not specifically identify the point in time that a project breaks even. Overall, DCF analysis is the most comprehensive technique.

A.6 Mill Closure Methodology

To determine the potential for uranium mills to close due to tailings disposal costs, we have performed a discounted cash flow analysis. This section describes the methodology in detail. The analysis is performed for each economic impact case and each model mill. The results of the analysis are presented in the next section.

Table A.15 shows an example of the DCF calculations for a small mill with a 7 million MT tailings pile, with 5 years remaining lifetime and subject to the control costs of Case 37. The first step in determining the cash flow is to project the annual quantity of U_3O_8 to be produced over the remaining lifetime of the mill. Production is based on the mill's capacity, the capacity utilization rate, the ore grade (assumed to be .1 percent), and the uranium recovery factor (assumed to be 93 percent). Production is expressed in terms of pounds of U_3O_8 (line 1). The capacity utilization rate used in the mill closure analysis is the industry average rate derived in the industry simulation described in Appendix B. This utilization rate projection is applied uniformly to each mill and for each impact case. The projected rate is 60 percent for 1983 and 1984 (years 1 and 2), 65 percent for 1985-87, 70 percent for 1988-89, and 75 percent for the remaining years.

The forecast of uranium price (line 2) was derived from DOE data sources and is explained in Appendix B. The ability of companies to pass-through disposal costs in terms of price increases is also considered in the DCF analysis (line 3). Total revenue (line 4) to the mill is derived by multiplying the uranium price (line 2 and line 3) by the production (line 1). The mill's cash flow (line 6) is estimated by multiplying the revenue estimated (line 4) by the assumed cash flow margin (line 5).

Table A.15. Discounted Cash Flow Analysis - CASE 37
Small Mill, 7 Million MT Pile, 5 Years Remaining
(1983 Dollars)

		YEAR				
		1	2	3	4	5
1.	U_3O_8 Production (Million lbs.)	0.40	0.40	0.43	0.43	0.43
2.	U_3O_8 Price ($/lb)	29.10	36.59	42.54	68.47	82.87
3.	Price Pass-through ($/lb)	0.00	0.00	0.00	0.00	0.00
4.	Revenue (Million $)	11.5	14.5	18.2	29.4	35.6
5.	Cash Flow Margin	0.20	0.20	0.20	0.20	0.20
6.	Cash Inflow (Million $)	2.30	2.90	3.65	5.87	7.11
7.	Control Costs-Existing Tailings (Million $)	4.44	4.44	4.44	4.44	4.44
8.	Control Costs-New Tailings (Million $)	1.19	1.19	1.28	1.28	1.28
9.	Net Cash Flow (Million $)	-3.33	-2.73	-2.07	0.15	1.39
10.	Discount Factor	.9091	.8265	.7513	.6830	.6209
11.	Discounted Net Cash Flow (Million $)	-3.03	-2.26	-1.56	0.10	0.86

12. Net Present Value (Million $) = -5.89

To determine the appropriate cash flow margin - the percent of revenues that is considered cash flow - we relied on the financial data of six companies in the uranium industry. These data are shown in Tables A.16 and A.17. As a group, these six companies provide a reasonable financial representation of the uranium industry. Although there are other companies in the industry, the financial results for those other companies contain insufficient information about uranium, or the results are not representative of the uranium industry. For example, Exxon Corporation and Union Carbide Corporation both have uranium operations, but the financial results of their uranium operations are a small part of the total company and are not identifiable from company financial statements.

The financial information has been assembled from corporate annual reports and Securities and Exchange Commission (SEC) 10-K reports. Many companies in the uranium industry have more than one business segment. The information shown in Tables A.16 and A.17 is for the business segment that includes uranium, although in many instances other products may also be included in the uranium business segment, such as other metals. Therefore, results should be compared over several years and among several companies for the results to be considered typical of the uranium industry.

For the purpose of this analysis, pre-tax cash flow generated from mill revenues is used to focus on the cash available to meet additional expenditures required for control of the tailings. Table A.17 has shown the industry ratios for the components of pre-tax cash flow. A cash flow margin of 20 percent on revenue is used (15 percent operating profit plus 5 percent depreciation and depletion). A cash flow margin of 20 percent is used to represent an average margin over the life of a project. Depreciation and depletion are frequently 10 percent or more; however, the excess above 5 percent is assumed to be committed to debt repayment or sustaining capital expenditures, or both. The principal difference between cash flow and operating profit is that cash flow includes depreciation and depletion, whereas operating profit does not. Depreciation and depletion are expenses for income tax calculations, but they are not cash expenses.

Annual control costs for each model mill are estimated separately for existing tailings and new tailings (see Table A.15). For existing tailings, the model pile costs of Table A.5 are spread equally over the first five years for all model mills (line 7). For new tailings, the annual control cost (line 8) is derived by multiplying the appropriate unit disposal cost from Table A.6 (converted to dollars per pound of U_3O_8) by the annual production estimate (line 1).

After the control costs are estimated, the net cash flow for each year can be calculated. The net cash flow (line 9) equals the cash flow (line 6) minus the control costs (line 7 and line 8). A discount factor (10 percent discount rate is assumed) (line 10) is then applied to the net cash flow (line 9) to give the discounted net cash flow (line 11). The sum of the annual discounted net cash flow estimates yields the net present value (line 12).

Table A.16. Financial Information for Selected Companies in the Uranium Industry
($ in Thousands)

	Year	Atlas	Conoco	Homestake	Kerr-McGee	Pioneer	UNC
Revenues	1976	15,611	NA	22,441	96,800	NA	29,339
	1977	28,152	NA	59,141	123,300	NA	80,816
	1978	26,845	16,488	44,928	115,200	13,810	133,193
	1979	38,253	16,384	42,388	163,400	20,267	181,626
	1980	60,148	34,586	45,363	238,900	7,829	167,811
	1981	NA	NA	59,983	201,500	7,224	102,102
	1982	NA	NA	63,702	153,100	419	84,038
Operating Profit	1976	4,607	NA	10,389	32,700	NA	7,103
	1977	8,027	NA	24,622	22,300	NA	28,539
	1978	(1,925)	(20,815)	20,454	20,100	1,257	42,320
	1979	(2,159)	(21,530)	14,097	(200)	(1,004)	61,339
	1980	6,142	(30,719)	(601)[a]	30,000	(1,082)	12,243
	1981	NA	NA	5,703	26,300	(7,855)	20,537
	1982	NA	NA	15,592	20,000	(63,871)	2,409
Assets	1976	NA	NA	14,144	215,300	NA	87,222
	1977	NA	NA	45,023	236,500	NA	145,376
	1978	56,375	52,491	42,990	272,000	51,119	203,041
	1979	79,428	61,218	47,790	288,400	70,583	279,436
	1980	72,834	62,867	54,798	304,800	84,046	239,888
	1981	NA	NA	83,135	304,500	85,859	210,471
	1982	NA	NA	80,831	312,400	35,621	209,791
Depreciation Depletion	1976	NA	NA	192	7,500	NA	1,070
	1977	NA	NA	80	9,300	NA	1,952
	1978	3,331	2,876	0	13,800	8,679	5,414
	1979	4,058	3,209	17	15,600	11,253	9,677
	1980	6,212	3,957	6,980	21,300	8,718	11,952
	1981	NA	NA	5,339	16,600	5,337	6,993
	1982	NA	NA	19,953	16,300	2,096	3,249
Capital Expend.	1976	NA	NA	2,036	NA	NA	27,856
	1977	NA	NA	2,628	NA	NA	54,499
	1978	14,579	7,213	7,961	34,277	19,467	49,518
	1979	21,870	6,937	8,533	28,800	23,513	39,156
	1980	7,453	7,999	12,521	17,900	17,567	46,662
	1981	NA	NA	12,036	14,200	9,238	14,386
	1982	NA	NA	1,025	7,300	3,123	8,606

NA = Not Available.

(a) Includes an $8,075 loss on settlement of uranium litigation, would otherwise have been (8,075) - 601 = +$7,474.

Source: Corporate annual reports, Securities and Exchange Commission (SEC) 10-K reports.

Table A.17. Financial Ratios for Selected Companies in the Uranium Industry
(Percentage)

	Year	Atlas	Conoco	Homestake	Kerr-McGee	Pioneer	UNC
Operating Profit/ Revenue	1976	29.5	NA	46.3	33.8	NA	24.2
	1977	28.5	NA	41.6	18.1	NA	35.3
	1978	-	-	45.5	17.4	9.1	31.8
	1979	-	-	33.3	-	-	33.8
	1980	10.2	-	16.5(a)	12.6	-	7.3
	1981	NA	NA	9.5	13.1	-	20.1
	1982	NA	NA	24.5	13.1	-	2.9
Operating Profit/ Assets	1976	NA	NA	73.4	15.2	NA	8.1
	1977	NA	NA	54.7	9.4	NA	19.6
	1978	-	-	47.6	7.4	2.5	20.8
	1979	-	-	29.5	-	-	22.0
	1980	8.4	-	13.6(b)	9.8	-	5.1
	1981	NA	NA	6.9	8.6	-	9.8
	1982	NA	NA	19.3	6.4	-	1.1
Depreciation Depletion/ Revenues	1976	NA	NA	1.8	7.7	NA	3.6
	1977	NA	NA	.3	7.5	NA	2.4
	1978	12.4	17.4	-	12.0	62.8	4.1
	1979	10.6	19.6	.04	9.5	55.5	5.3
	1980	10.3	11.4	15.4	8.9	111.0	7.1
	1981	NA	NA	8.9	8.2	73.9	6.8
	1982	NA	NA	31.3	10.6	500.2	3.9
Capital Expenditure/ Revenue	1976	NA	NA	9.1	NA	NA	95.0
	1977	NA	NA	4.4	NA	NA	67.4
	1978	54.3	43.7	17.7	29.8	141.0	37.2
	1979	57.2	42.3	20.1	17.6	116.0	21.6
	1980	12.4	23.1	27.6	7.5	224.0	27.8
	1981	NA	NA	20.1	7.0	127.9	14.1
	1982	NA	NA	1.6	4.8	745.3	10.2

NA = Not Available.

- = Loss Year.

(a)16.5 percent without litigation.

(b)13.6 percent without litigation.

Source: Corporate annual reports, Securities and Exchange Commission (SEC) 10-K reports.

As discussed in Section A.5, if the net present value (NPV) of the cash flows is positive, then the project should be accepted or, in this case, the mill should remain open. If the NPV is negative, the mill should close. For conservatism, we have assumed for this analysis that if the NPV is less than $1 million, then the mill would cease operation.

The mill closure analysis is applicable to all existing mills regardless of whether a mill is currently operating or on standby. The closure decision, as determined by this methodology, is essentially the same in either case. In both cases, the mill's expected future cash flow is compared to its expected tailings disposal costs. The intent is to determine not whether mills will operate in the future, per se, but rather to see if the tailings disposal costs, not other factors, provide a significant obstacle to future operation. As discussed in Chapter 5, mills have closed for a variety of reasons unrelated to control of mill tailings. For a mill currently operating with economic life remaining, the closure decision determines if the tailings disposal cost (not market conditions or other reasons) will prevent the mill from continuing its operations in the future. For a mill on standby due to market conditions but also with economic life remaining, the closure decision determines if the tailings disposal costs will prevent a mill from reopening sometime in the future. Consequently, the mill closure analysis does not distinguish between mills that are currently operating and those that are on standby.

Tables A.18.a, A.18.b, and A.18.c present the estimated net present values for all 25 economic impact cases and each model mill.

A.7 Mill Closure Results

The model mill closure determinations are based on the estimates of the net present value of the cash flows. The results for each economic impact case are summarized below. These results assume a cash flow margin of 20 percent and complete cost absorption by the model mills. Because there are three different sizes of model mills, the results are converted to the common denominator of equivalent number of small mills to allow direct comparison of different cases. Based on mill capacity, one medium mill is equivalent to two small mills, and one large mill is equivalent to four small mills. Thus, the total of 24 mills in the industry can be converted to the equivalent of 54 small mills [(8 small mills x 1) + (9 medium mills x 2) + (7 large mills x 4) = 54 small mill equivalents].

Economic Impact Case	Model Mill Closures	Equivalent Number of Small Mills
1-8, 10-12, 26-31, 34	No closures	0
9, 13, 32, 33 35, 36	1 small	1
37	2 small	2

Table A.18.a. Net Present Value for a Small Model Existing Mill
(Millions of 1983 Dollars)

Economic Impact Case	2(a)			7(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
# of Mills	1	1	2	1	3	0
1	15.66	35.22	46.84	15.66	35.22	46.84
2	12.41	31.92	43.51	10.74	30.25	41.84
3	10.34	29.83	41.41	7.68	27.17	38.74
4	8.56	28.04	39.60	4.93	24.41	35.98
5	12.87	32.18	43.63	10.58	29.93	41.41
6	10.77	30.04	41.47	7.36	26.68	38.15
7	8.91	28.14	39.55	4.44	23.74	35.18
8	6.88	26.06	37.44	1.23	20.50	31.93
9	5.00	24.15	35.51	-1.62	17.62	29.03
10	10.77	30.04	41.47	7.36	26.68	38.15
11	8.91	28.14	39.55	4.44	23.74	35.18
12	6.88	26.06	37.44	1.23	20.50	31.93
13	5.00	24.15	35.51	-1.62	17.62	29.03
26	10.39	28.45	39.11	8.72	26.78	37.44
27	8.01	25.84	36.34	5.36	23.19	33.69
28	5.91	23.47	33.81	2.27	19.83	30.17
29	11.15	29.21	39.86	8.80	26.86	37.51
30	8.68	26.44	36.90	5.19	22.95	33.42
31	6.50	23.99	34.29	1.95	19.44	29.74
32	4.13	21.35	31.46	-1.63	15.59	25.70
33	1.94	18.89	28.83	-4.81	12.14	22.08
34	7.51	24.42	34.34	4.02	20.93	30.85
35	5.39	22.10	31.88	0.85	17.55	27.34
36	3.06	19.50	29.12	-2.70	13.74	23.36
37	0.91	17.12	26.58	-5.84	10.37	19.84

(a) Size of existing tailings pile, million MT.

Table A.18.b. Net Present Value for a Medium Model Existing Mill (Millions of 1983 Dollars)

Economic Impact Case	2(a)			7(a)		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
# of Mills	0	2	2	0	4	1
1	31.32	70.45	93.68	31.32	70.45	93.68
2	28.00	67.02	90.20	26.33	65.36	88.53
3	25.90	64.90	88.05	23.24	62.22	85.36
4	24.10	63.05	86.17	20.48	59.44	82.57
5	28.17	66.78	89.69	25.95	64.64	87.60
6	26.02	64.55	87.41	22.69	61.33	84.25
7	24.11	62.57	85.39	19.73	58.31	81.21
8	22.01	60.39	83.15	16.48	55.02	77.89
9	20.09	58.39	81.10	13.59	52.06	74.88
10	26.02	64.55	87.41	22.69	61.33	84.25
11	24.11	62.57	85.39	19.73	58.31	81.21
12	22.01	60.39	83.15	16.48	55.02	77.89
13	20.09	58.39	81.10	13.59	52.06	74.88
26	23.96	60.08	81.40	22.29	58.42	79.73
27	21.26	56.91	77.92	18.61	54.26	75.27
28	18.79	53.91	74.59	15.15	50.27	70.95
29	24.72	60.84	82.16	22.37	58.49	79.80
30	21.84	57.35	78.28	18.35	53.87	74.79
31	19.29	54.28	74.87	14.74	49.73	70.32
32	16.53	50.96	71.19	10.77	45.20	65.43
33	13.97	47.86	67.74	7.22	41.11	60.99
34	19.48	53.31	73.15	16.00	49.82	69.67
35	17.08	50.49	70.06	12.53	45.94	65.51
36	14.38	47.26	66.50	8.62	41.50	60.74
37	11.91	44.32	63.25	5.16	37.57	56.50

(a) Size of existing tailings pile, million MT.

Table A.18.c. Net Present Value for a Large Model Existing Mill
(Millions of 1983 Dollars)

Economic Impact Case	2[a]			7[a]			22[a]		
	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS	5 YRS	10 YRS	15 YRS
# of Mills	0	0	1	1	1	1	1	1	1
1	62.64	140.89	187.37	62.64	140.89	187.37	62.64	140.89	187.37
2	59.18	137.23	183.58	57.51	135.57	181.91	54.11	132.12	178.44
3	57.04	135.03	181.33	54.36	132.32	178.61	49.16	127.14	173.45
4	55.17	133.07	179.32	51.57	129.49	175.75	44.87	122.87	169.19
5	58.77	135.99	181.80	56.67	134.06	179.98	51.81	129.69	175.92
6	56.51	133.58	179.29	53.33	130.61	176.47	46.50	124.38	170.61
7	54.51	131.44	177.07	50.30	127.47	173.25	41.77	119.63	165.84
8	52.29	129.05	174.56	46.99	124.07	169.80	36.34	114.11	160.27
9	50.26	126.86	172.27	44.00	120.95	166.59	31.64	109.41	155.57
10	56.51	133.58	179.29	53.33	130.61	176.47	46.50	124.38	170.61
11	54.51	131.44	177.07	50.30	127.47	173.25	41.77	119.63	165.84
12	52.29	129.05	174.56	46.99	124.07	169.80	36.34	114.11	160.27
13	50.26	126.86	172.27	44.00	120.95	166.59	31.64	109.41	155.57
26	51.11	123.35	165.98	49.44	121.68	164.31	46.11	118.35	160.97
27	47.75	119.05	161.07	45.10	116.40	158.42	39.87	111.16	153.18
28	44.55	114.80	156.15	40.91	111.16	152.51	34.09	104.34	145.68
29	51.87	124.11	166.74	49.52	121.76	164.39	43.98	116.23	158.85
30	48.14	119.18	161.03	44.66	115.69	157.55	37.00	108.04	149.89
31	44.87	114.85	156.03	40.32	110.30	151.48	30.84	100.83	142.01
32	41.33	110.19	150.64	35.57	104.42	144.88	23.97	92.83	133.28
33	38.01	105.80	145.57	31.27	99.05	138.82	17.77	85.55	125.32
34	43.44	111.09	150.78	39.95	107.61	147.29	32.30	99.95	139.63
35	40.46	107.27	146.42	35.91	102.72	141.87	26.43	93.24	132.39
36	37.03	102.79	141.26	31.27	97.03	135.50	19.67	85.43	123.90
37	33.90	98.71	136.58	27.15	91.97	129.84	13.65	78.47	116.34

[a] Size of existing tailings pile, million MT.

A.8 Sensitivity Analysis

To supplement the above closure results, a sensitivity analysis was performed which varied two parameters: the cash flow margin and the assumption of complete cost absorption by the model mills. The cash flow margin is varied from 20 percent to 25 percent, and then 15 percent. The assumption of complete cost absorption has the greatest economic impact on the model mills. If the control costs can be completely or partially passed-through in the form of price increases, this will lessen the impact on the mills. Some pass-through is probable for several reasons. First, all of the existing mills plus any new mills will be subject to control costs. Therefore, although there may be different levels of control costs within the industry, the industry as a whole should pass-through control costs to some extent. Second, as discussed in Appendix B, demand for yellowcake is inelastic with respect to price. Finally, long-term contracts for U_3O_8 frequently contain cost escalation clauses. Two pass-through scenarios were analyzed: a $1 and $2 per pound increase in the price of U_3O_8.

Table A.19 presents the results of the sensitivity analysis for each economic impact case. There are 9 different scenarios which have been analyzed (3 cash flow margins x 3 cost absorption/pass-through assumptions). Since there are 25 economic impact cases, this yields 225 separate mill closure results, all of which are expressed in this table in terms of small mill equivalents. The findings of this analysis are discussed below.

Cash Flow Margin

Selection of the cash flow margin has a noticeable impact on the mill closure analysis. For the six cases which show one small mill closure under the conditions of a 20 percent cash flow margin and 100 percent cost absorption, all but one case has no closures when a 25 percent cash flow margin is assumed. Case 37, which had two small mill closures with a 20 percent margin, shows one closure with a 25 percent margin. In the other direction, assuming a margin of 15 percent results in 14 of the impact cases indicating closures. Except for Case 37, all of these cases yield one or two small mill closures under the 15 percent cash flow margin. Six small mill equivalents are estimated to close for Case 37 under the 15 percent margin (and no pass-through), compared to two under the 20 percent assumption.

Cost Absorption/Pass-Through Assumptions

The cost absorption/pass-through assumption also influences the mill closure analysis. For the six cases with one small mill closure under the conditions of a 20 percent cash flow margin and no pass-through, a $1 per pound pass-through eliminates the closure in one case, while a $2 per pound pass-through eliminates the closure in four additional cases. For Case 37, the two small mill closures under cost absorption and a 20 percent margin are reduced to one with either a $1 or $2 per pound pass-through. Also, the six small mill equivalents closing under cost absorption and a 15 percent margin are reduced to two with a $1 per pound pass-through.

Table A.19. Summary of Model Mill Closure Results[a]

Economic Impact Case	Cost Absorption			$1 Price Increase			$2 Price Increase		
	25%	20%	15%	25%	20%	15%	25%	20%	15%
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0
7	0	0	1	0	0	0	0	0	0
8	0	0	1	0	0	1	0	0	1
9	0	1	1	0	1	1	0	0	1
10	0	0	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0
12	0	0	1	0	0	1	0	0	1
13	0	1	1	0	1	1	0	0	1
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0
28	0	0	1	0	0	1	0	0	0
29	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0
31	0	0	1	0	0	1	0	0	0
32	0	1	2	0	1	1	0	0	1
33	1	1	2	1	1	2	0	1	1
34	0	0	1	0	0	0	0	0	0
35	0	1	1	0	0	1	0	0	1
36	0	1	2	0	1	2	0	1	1
37	1	2	6	1	1	2	0	1	2

[a] Expressed in terms of small mill equivalents.

REFERENCES FOR APPENDIX A

DOE82 U.S. Department of Energy, Commingled Uranium Tailings Study, Volume II, Technical Report, DOE/DP-0011, June 30, 1982.

EMJ79 Engineering and Mining Journal, July 1979, Page 173.

NRC80 U.S. Nuclear Regulatory Commission, Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706, September 1980.

Appendix B

Projections of Price, Demand, and Production

B.1 Overview

The purpose of this appendix is to present the projections of demand, price, and production of uranium for the years 1983 through 2000. These projections, which are based on projections provided to us by the Department of Energy, Energy Information Administration (EIA), are used to estimate the industry-wide cost of mill tailings disposal and the associated economic impacts of several alternative standards. The estimates of uranium production at conventional mills are converted to generation of mill tailings and thus form the basis of the industry cost estimates presented in Chapter 5. The effects of control-caused mill closures (see Appendix A) on industry capacity and production are also analyzed in this appendix.

B.2 Baseline Projection

To obtain the best estimates of future uranium industry activities, we solicited EIA to provide us with a set of projections from which we could estimate the economic impacts of the alternative tailings standards. It became readily apparent that a new set of projections constructed from their models had to be developed since the information in their most recent publications was inadequate for our purposes. In EIA's most detailed study on the uranium industry, published in March 1983 (DOE83a), their projections of uranium demand, imports, domestic production, and prices were based on their mid-case forecast of U.S. reactor capacity published in their 1981 Annual Report to Congress. This forecast calls for installed reactor capacity of 165 GWe by the year 2000 and is substantially higher than EIA's most recent mid-case forecast of 130 Gwe. EIA's most recent forecasts are published in their 1982 Annual Energy Outlook (DOE83b); however, this report contains no information on uranium industry activities. EIA, thus, committed staff resources to performing computer runs on their uranium industry model (EUREKA) with an updated set of uranium demand estimates (see DOE83a for a description of the EUREKA model). The projections developed in this RIA rely very heavily on the output from these computer runs.

B.2.1 Industry Demand and Conventional Mill Production

In the RIA for the proposed standards, we developed two industry demand scenarios which were derived from the mid-case and firm nuclear base case contained in EIA's 1980 Annual Report to Congress. In their most recent set of forecasts presented in the 1982 Annual Energy Outlook, EIA has dropped the firm nuclear base scenario and developed only three forecasts - low, mid, and high. Table B.1 presents the annual projections of reactor capacity through the year 2000 for both the low and high cases, as well as the percentage difference estimated for each year. The percent difference between the two cases ranges from 5 percent for the year 1989 to 27 percent for the year 2000, with the average difference (in gigawatt-years) over the entire time period being 14 percent. In March 1983, the EIA Administrator presented at a conference two sets of EIA forecasts of uranium requirements which correspond to the low and high reactor capacity cases (Ev83). These two forecasts, as well as their percentage difference, are also presented in Table B.1. The difference between the high and low case (ignoring 1983) ranges from 5 percent for 1986 to 35 percent for the year 2000, with the average over the entire period being 17 percent. Based on these two comparisons, we concluded that the different forecasts were not far enough apart to warrant the development of two baseline (no EPA standard) projections as we did in the RIA for the proposed standards.

EIA developed a single projection of uranium industry demand which served as the starting point for the EUREKA computer runs. The first ten years of the projection is based primarily on information from EIA's latest (January 1983) uranium market survey (DOE83d) and represents the survey's estimates of utilities' committed deliveries of uranium to DOE enrichment plants. For the remaining years, the projection represents EIA's estimate of uranium requirements under their mid-case scenario. Table B.2 presents the complete projection of industry demand derived by EIA.

Industry demand and domestic production are related by the following identity:

Industry Demand = Change in Inventories + Net Imports + Domestic Production

To derive a baseline projection of domestic production, we must therefore make some assumptions about imports and inventory adjustments. EIA performed their computer runs using two different import scenarios. The first, referred to as the "Pure Price Competition" case, assumes a free market and allows the relative economics of domestic and foreign uranium production to dictate how utilities will purchase uranium. The second scenario, called the "Utility Preference" case, assumes that utilities will purchase foreign uranium only up to a self-imposed limit which has been defined by EIA as 40 percent of demand. Although this containment is self-imposed by the utilities, it is essentially the same as a 40 percent embargo limit. Descriptions of these two cases are presented in EIA's recent study of the uranium industry (DOE83a). These two import scenarios are extremes, neither of which is likely to occur. However, the results from these two cases provide reasonable bounds on what the uranium industry will be like in the future. Table B.3 presents the annual import share of industry demand for these two cases, as derived from the EUREKA output. For use in this RIA, we assumed the average of

Table B.1. Department of Energy Projections of Reactor Capacity and Uranium Requirements, 1983-2000

Year	Installed Reactor Capacity (GWe)			Uranium Requirements (10^3 ST U_3O_8)		
	Low Case	High Case	% Diff.	Low Case	High Case	% Diff.
1983	62	69	11	16.3	16.3	0
1984	66	77	17	17.5	19.0	9
1985	72	90	25	18.0	19.0	6
1986	83	101	22	17.5	18.3	5
1987	94	101	7	17.4	18.7	7
1988	103	113	10	18.7	20.8	11
1989	110	115	5	18.8	21.7	15
1990	112	121	8	18.7	21.7	16
1991	114	122	7	18.5	21.2	15
1992	114	125	10	18.2	20.8	14
1993	114	127	11	18.7	22.5	20
1994	113	127	12	18.8	23.1	23
1995	113	127	12	19.0	22.2	17
1996	113	131	16	18.5	21.8	18
1997	113	133	18	17.6	22.2	26
1998	112	136	21	17.7	24.0	36
1999	111	138	24	18.6	25.0	34
2000	110	140	27	18.8	25.4	35
Cumulative Total	1829	2093	14	327.3	383.7	17

Source: Installed reactor capacity: Roger Diedrich, "Estimates of Future vs Nuclear Power Growth," U.S. Department of Energy, Energy Information Administration, SR-NAFD-83-01, January 1983 (Also summarized in DOE83b).

Uranium requirements: J. Erich Evered, "Outlook for U.S. Energy Demand and Supply - The Role of Nuclear Power," presented at Atomic Industrial Forum Fuel Cycle Conference, Kansas City, Missouri, March 21, 1983.

Table B.2. Industry Demand, 1983-2000

Year	10^3 ST U_3O_8	Year	10^3 ST U_3O_8
1983	14.0	1991	20.3
1984	17.5	1992	20.2
1985	18.8	1993	20.9
1986	19.5	1994	21.7
1987	18.0	1995	22.5
1988	22.0	1996	22.8
1989	19.5	1997	23.5
1990	20.0	1998	25.4
		1999	27.7
		2000	29.7

Source: U.S. Department of Energy, Energy Information Administration (Gene Clark), July 11, 1983.

Table B.3. Penetration of Uranium Imports, 1983-2000
(percent of industry demand)

Year	Pure Price Competition Case (imports plus shortfall)	Utility Preference Case	Percent Assumed for RIA
1983	18	18	18
1984	17	17	17
1985	18 (33)	18	18
1986	20 (38)	20	20
1987	19 (33)	19	25
1988	34 (48)	30	35
1989	24 (26)	29	27
1990	34	29	31
1991	23	23	23
1992	22	16	19
1993	22	21	21
1994	32	27	29
1995	40	31	35
1996	44	30	37
1997	56	34	45
1998	65	36	51
1999	72	36	54
2000	65	37	51

Source: Calculated from EUREKA computer runs, prepared by U.S. Department of Energy, Energy Information Administration (Gene Clark), July 11, 1983.

these two sets of estimates for most of the years in the projection period. For five of the years, an unexplained shortfall turned up in the EUREKA output so that we judgmentally assumed an import share for those years. The import share assumed in this RIA is also shown in Table B.3. The changes in inventory levels were essentially the same for each import scenario so that no interpolation of the EUREKA output was required.

With the projections of demand, imports, and inventory adjustments in place, we calculated the domestic production for each year according to the identity stated above. Once the projection of domestic production was established, we had to then determine how much of it will be produced at conventional uranium mills. As explained in Chapter 2, the conventional mill share of domestic production was historically about 90 percent, but this has decreased to 85 percent in 1980, 81 percent in 1981, and 75 percent in 1982. We expect nonconventional sources of uranium production to continue their already significant penetration into the market, but we have no basis for evaluating the degree of this penetration or the time frame over how long it will occur. For purposes of projecting conventional mill production and mill tailings generation, we arbitrarily assumed that the nonconventional sources would maintain their 25 percent share of the market over the entire time period under consideration. Table B.4 presents the baseline projections for industry demand, change in inventory levels, imports, total domestic production, and production at conventional mills.

B.2.2 Mill Capacity, Market Closures, and Segmentation of Production by Existing and New Mills

The primary purpose in projecting the production at conventional uranium mills is to determine the amount of future tailings that will be generated so that we can estimate the total cost of the alternative disposal standards. Since future tailings disposal costs differ according to whether they are added to existing impoundments or placed in new piles, we need to estimate how much of the future tailings are expected to be generated at existing mills versus new mills. To make this determination, we need to know for each year how much capacity is available at existing mills and how much new mill capacity must be introduced in order to meet the demand for conventionally-produced uranium. To do this, we have developed a model of the conventional milling sector which takes into account the following:

- amount of capacity which is in operation;
- capacity which is available but is on standby due to market conditions;
- capacity which is permanently retired due to its economic life being exhausted;
- introduction of new mill capacity;
- industry average capacity utilization rate (for mills in operation only).

Table B.4. Derivation of Projection of Uranium Production
by Conventional Mills, 1983-2000
(thousand MT U_3O_8)

Year	Industry Demand	Change in Inventories	Net Imports	Total Domestic Production	Domestic Production, Conventional (75% of Total)
1983	12.7	-0.4	2.3	10.0	7.5
1984	15.9	-4.8	2.7	8.4	6.3
1985	17.1	-4.2	3.1	9.8	7.3
1986	17.7	-3.8	3.5	10.4	7.8
1987	16.3	-3.3	4.1	8.9	6.7
1988	20.0	-3.1	7.0	9.9	7.4
1989	17.7	-2.7	4.8	10.2	7.6
1990	18.1	+0.2	5.6	12.7	9.5
1991	18.4	-1.9	4.3	12.2	9.2
1992	18.3	-1.4	3.4	13.5	10.2
1993	19.0	-1.2	4.0	13.8	10.3
1994	19.7	-0.8	5.7	13.2	10.0
1995	20.4	+0.8	7.2	14.0	10.5
1996	20.7	+0.2	7.6	13.3	10.0
1997	21.3	+0.6	9.6	12.3	9.3
1998	23.0	+1.8	11.8	13.0	9.7
1999	25.1	+2.1	13.6	13.6	10.2
2000	26.9	+1.9	13.7	15.1	11.3

Our model is based on the concept of annual average capacity which is defined as the average between the capacity existing at the beginning of the year and the capacity existing at the end of the year. The annual average capacity estimates are made separately for mills which are in operation and those on standby. The average operational capacity for any year is driven by the following identity:

Production = Operational Capacity x Capacity Utilization Rate

Conventional production (derived in the previous section) and the capacity utilization rate are both exogenously determined, and together they determine how much industry capacity must be in operation in order to meet demand. The average capacity estimates are not directly comparable to industry capacity estimates taken at a single point in time since the average capacity pertains to the average amount of capacity that must be in operation throughout the entire year. Fluctuations in capacity during the course of the year are not taken into account in this analysis, so that many combinations of shutdowns/startups could yield the same average for the year. The average capacity utilization rate in 1982 was 65 percent (the basis of which is described below). We judgmentally assigned values for the rate over the entire projection period, as follows: 60 percent for 1983 and 1984, 65 percent for 1985 through 1987, 70 percent for 1988 and 1989, and 75 percent for 1990-2000. These values were based on the yearly changes in demand for conventionally-milled uranium and reflect increases where noticeable increases in demand take place.

How the year-to-year changes to the estimated average operational capacity should be made are determined by the following equation:

$$AOC_t = AOC_{t-1} - OC_t + \Delta AOC_t$$

where: AOC_t = Average operating capacity in year t
OC_t = Obsolete capacity in year t
ΔAOC_t = Change in average operating capacity

Solving this equation for ΔAOC, if the calculation is positive, then an addition to average operating capacity is made. This can take place in one of two ways - either mills on standby can reopen or new mills can be constructed. We have assumed that no new mills will be introduced until all the standby capacity has been reopened. If the calculation of ΔAOC is negative, than a market closure takes place which, thus, increases the level of standby capacity which is available for reopening in the future. In this manner, one can see on a year-to-year basis if the changes in average operating capacity required to meet demand (exogenously determined) result in market closures, reopenings of existing mills, or startup of new mills. All changes are assumed to take place immediately at the beginning of each year, so that the mathematical relationship of production, capacity, and utilization rate still holds for each year.

Obsolete capacity in any year is estimated by multiplying an obsolescence rate by the prior year's average operating capacity. The assumed obsolescence rate is .047, based on an estimated average mill life expectancy of 21.3 years. Generally, the life expectancy of a mill is at least as long as the life of the surrounding ore deposits (Lo81). Based upon a sample of 11 mills, an average total life was calculated by adding the actual years of operation with the expected remaining life of the surrounding ore deposits. This calculation resulted in an average mill life expectancy of 21.3 years.

By estimating the yearly closures or additions (reopenings or new mills) to operating capacity, we can keep a running tabulation of existing mill capacity and new mill capacity in operation for each year. These estimates provide the basis for segmenting the total conventional production into that taking place at existing mills versus that at new mills. The same average capacity utilization rate is applied to the respective operational capacity estimates to yield production at existing and new mills.

Table B.5 presents the complete set of projections for the conventional milling sector. Before these projections were made, however, we had to estimate the average operational and standby capacity for 1982. We used two alternative methods for estimating these values, with both methods producing virtually the same estimates. In the first method, we used data from the 1982 (DOE82) and 1983 (DOE83c) Statistical Data of the Uranium Industry. This source presents capacity estimates for mills in operation as of January 1 of each year. As of January 1, 1983, 14 mills were in operation with a total capacity of 33,650 ST (30,600 MT) ore/day. DOE estimates that this ore capacity corresponds to about 9,000 to 13,000 ST U_3O_8 per year. Assuming the midpoint of the range and converting to MT results in capacity of 10,000 MT U_3O_8/year for the 14 mills in operation. There were also 10 mills on standby as of this date representing ore capacity of 19,200 MT ore/day. To convert this estimate to MT of U_3O_8 per year, we assumed the same ratio of ore/day capacity to U_3O_8/year capacity as for the 14 mills in operation. This assumes that the product of the average ore grade and the average uranium recovery rate is the same for both sets of mills. The result from this calculation is that there were 6,300 MT U_3O_8/year capacity on standby as of January 1983. This same procedure was repeated for data presented in the 1982 report. As of January 1, 1982, 20 mills were in operation accounting for an estimated 18,100 MT U_3O_8/year capacity, and 3 mills on standby representing capacity of 1,600 MT U_3O_8/year. Since average capacity is determined as the average of the capacity at the beginning and end of the year, we used the average of the January 1, 1982/January 1, 1983 estimates to derive the capacity for 1982. The results were 14,100 MT U_3O_8 per year for operational capacity and 4,000 MT U_3O_8 per year for standby capacity. Since production at conventional mills in 1982 was 9,200 MT U_3O_8 (DOE83c), the capacity utilization rate was estimated as 65 percent.

Table B.5. Baseline Projection of Conventional Mill Capacity and Production
(Thousands of Metric Tons of U_3O_8)

	Conven. Demand	Obsolete Capacity	Closures		Additional Capacity		Avg Capacity		Capacity Util. Rate	Production		
			Reg.	Mkt.	Reopened	New	Oper.	Standby		Total	Old	New
1983	7.5	0.7	0.0	1.0	0.0	0.0	12.4	5.0	.60	7.5	7.5	0.0
1984	6.3	0.6	0.0	1.4	0.0	0.0	10.5	6.4	.60	6.3	6.3	0.0
1985	7.3	0.5	0.0	0.0	1.2	0.0	11.2	5.2	.65	7.3	7.3	0.0
1986	7.8	0.5	0.0	0.0	1.3	0.0	11.9	3.9	.65	7.8	7.8	0.0
1987	6.7	0.6	0.0	1.1	0.0	0.0	10.3	5.0	.65	6.7	6.7	0.0
1988	7.4	0.5	0.0	0.0	0.8	0.0	10.6	4.2	.70	7.4	7.4	0.0
1989	7.6	0.5	0.0	0.0	0.7	0.0	10.8	3.5	.70	7.6	7.6	0.0
1990	9.5	0.5	0.0	0.0	2.4	0.0	12.7	1.1	.75	9.5	9.5	0.0
1991	9.2	0.6	0.0	0.0	0.2	0.0	12.3	0.9	.75	9.2	9.2	0.0
1992	10.2	0.6	0.0	0.0	0.9	1.0	13.6	0.0	.75	10.2	9.5	0.7
1993	10.3	0.6	0.0	0.0	0.0	0.7	13.7	0.0	.75	10.3	9.0	1.3
1994	10.0	0.6	0.0	0.0	0.0	0.3	13.3	0.0	.75	10.0	8.5	1.5
1995	10.5	0.6	0.0	0.0	0.0	1.3	14.0	0.0	.75	10.5	8.0	2.5
1996	10.0	0.7	0.0	0.0	0.0	0.0	13.3	0.0	.75	10.0	7.5	2.5
1997	9.3	0.6	0.0	0.3	0.0	0.0	12.4	0.3	.75	9.3	6.8	2.5
1998	9.7	0.6	0.0	0.0	0.3	0.8	12.9	0.0	.75	9.7	6.6	3.1
1999	10.2	0.6	0.0	0.0	0.0	1.3	13.6	0.0	.75	10.2	6.2	4.1
2000	11.3	0.6	0.0	0.0	0.0	2.1	15.1	0.0	.75	11.3	5.7	5.6

The second method was to calculate the sum of the individual mill capacities, expressed in U_3O_8/year, directly for the mills in operation and on standby for the same two dates, based on individual mill capacity estimates contained in a report prepared by the Colorado Nuclear Corporation (CNC82). The estimates for January 1, 1983, using this method were 11,700 MT U_3O_8/year for operational capacity and 6,000 for standby capacity. For January 1, 1982, the capacities were 16,000 for operational and 1,500 for standby. The average of these two sets of estimates, yielding the 1982 annual estimate, were 13,900 MT U_3O_8/year for operational capacity and 3,800 MT U_3O_8/year for standby. These estimates were each only 200 MT U_3O_8/year different from the first method using the DOE data. We selected the first set of estimates since we could use the same estimation procedure on past or future DOE data to assemble a consistent set of estimates. These estimates for 1982 are necessary in order to estimate the obsolete capacity and the market closures for 1983.

The projections presented in Table B.5 indicate the following about future uranium industry activity. In response to the continuing decline in demand for conventionally-milled uranium through 1984, we project that additional market closures will occur in 1983 and 1984. A drop in production in 1987 will also result in market closures for that year. Conventional mill production will not return to its 1982 level until 1990. Standby capacity is sufficiently large in relation to expected growth in demand so that it is not completely exhausted (i.e., reopened) until 1992, the year in which new mills are first introduced. Cumulative uranium production from 1983 through the year 2000 totals about 160,000 MT U_3O_8, which translates into about 175 million MT of mill tailings, based on an average ore grade of .1 percent and an average uranium recovery rate of 93 percent. Approximately 150 million MT of tailings will be generated at existing mills and 25 million MT at new mills.

These projections are based on a series of judgments about the relationship of different parameters to one another and the values selected for these parameters. Based on these judgments, we believe that the projections are reasonable. A different set of judgments will clearly result in different projections, which may or may not be a more accurate presentation of the industry's future. For instance, based on the assumption that new mill capacity will not be introduced until all the mills on standby have reopened, together with the estimates of industry demand to be supplied by conventional mills, we estimate that new mills will not be required to begin operations until 1992. This does not mean that we believe it is impossible or even highly unlikely that a new mill will begin operations before 1992. This projection does mean that if one believes that both the constraint on new mill capacity presented by standby capacity and the demand estimates are reasonable, then there is enough standby capacity available so that new mills need not become operational before this time.

As explained in Chapter 2, there is a great deal of uncertainty associated with making long-term projections of the uranium industry. The primary purpose of these projections, however, is to establish a reasonable baseline from which we can estimate the incremental economic impacts of tailings disposal. The projections are not necessarily intended to be a highly accurate forecast of the uranium industry activities, although we attempted to put together the best forecast we could within the constraints of time, financial resources, readily available data, and the inherent uncertainty of such a task.

B.2.3 Uranium Prices

An annual forecast of uranium prices is required to perform the mill closure analysis presented in Appendix A. Since this analysis estimates future revenues of model mills, the price that is needed is that for deliveries of uranium each year. This price contrasts with the more widespread use of market uranium prices which provide the base for consummation of long-term contracts. Since delivered uranium prices are projected by the EUREKA model, we relied on the two sets of computer runs performed by DOE to provide a basis for this projection. These two projections of delivered uranium prices for the cases of pure price competition and utility preference are presented in Table B.6. These two sets of estimates are virtually the same for 1983 through 1986, but thereafter they diverge significantly. As discussed above, the most likely point between these extremes is not readily discernible. Therefore, we took the average of the two price projections for use in this RIA. The average of the DOE estimates was escalated to 1983 dollars from 1981 dollars by a factor of 10.8 percent, the estimated change in the GNP implicit price deflator (DOE83b).

For comparison, we present the market price projections made by the Colorado Nuclear Corporation in November 1982. Although market prices may differ substantially from delivered prices in the short-run since contracts for deliveries in the near-term may have been established several years ago when conditions in the uranium industry were much different, in the long-run the two should converge reasonably closely or at least follow the same trend. The Colorado Nuclear Corporation projections are also based on the output from the EUREKA model. The market scenarios selected from this study are the two that most closely correspond to the two DOE scenarios. Mid-case demand, although different than the DOE demand projection, was assumed under the alternative import scenarios of no embargo and a 37 1/2 percent import limit. These two market price projections are displayed in Figure B.1. As the figure indicates, market prices for both scenarios reach about \$90 per pound of U_3O_8 (January 1982 dollars) by the late 1980's, then fall to about \$50 per pound by the early 1990's. At this point, the two projections diverge. Under the import limit scenario, the price increases to about \$115 per pound by 1996, before dropping rapidly. Under the no embargo case, the market price increases to about \$60 per pound by 1996, drops to about \$35 per pound by 1998, and increases again to more than \$50 per pound in the year 2000. Our projection of delivered uranium prices falls between these two cases.

Table B.6. Annual Average Delivered Uranium Price, 1983-2000
($ per pound of U_3O_8)

Year	Pure Price Competition Case (1981 $)	Utility Preference Case (1981 $)	Average (1981 $)	Average (1983 $)
1983	26.23	26.28	26.26	29.10
1984	32.88	33.15	33.02	36.59
1985	38.33	38.44	38.39	42.54
1986	60.71	62.88	61.80	68.47
1987	67.03	82.54	74.79	82.87
1988	69.05	98.81	83.93	92.99
1989	64.02	102.20	83.11	92.09
1990	59.63	98.93	79.28	87.84
1991	54.14	93.73	73.94	81.93
1992	47.91	86.84	67.38	74.66
1993	47.54	88.28	67.91	75.24
1994	47.00	92.10	69.55	77.06
1995	47.49	95.36	71.43	79.14
1996	46.94	98.15	72.55	80.39
1997	71.81	96.62	84.22	93.32
1998	68.26	92.85	80.56	89.26
1999	64.20	87.18	75.69	83.86
2000	60.26	83.98	72.12	79.91

Source: EUREKA computer runs prepared by U.S. Department of Energy, Energy Information Administration (Gene Clark), July 11, 1983.

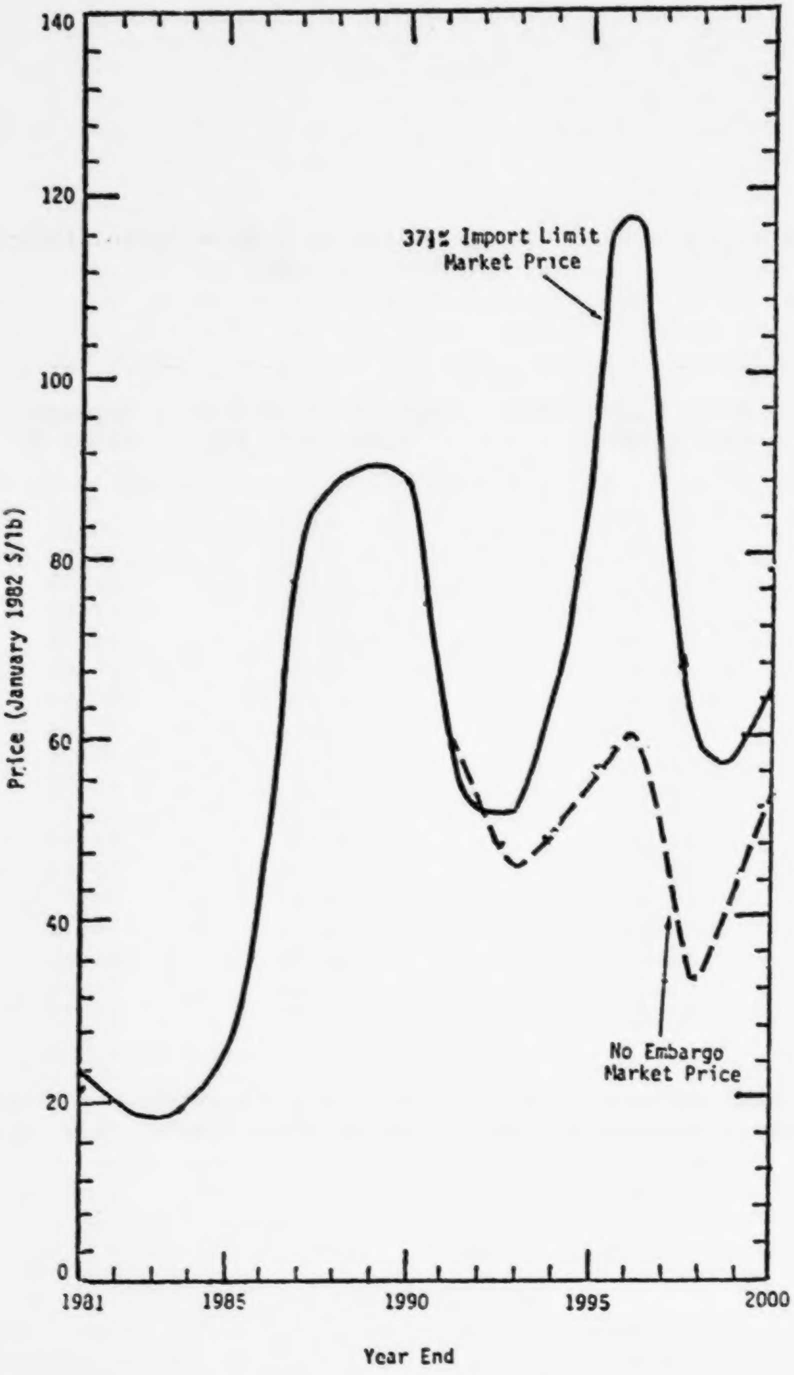

Figure B.1. Alternative Market Price Projections by Colorado Nuclear Corporation

Source: Colorado Nuclear Corporation and Pickard, Lowe, and Garrick, Inc., Natural Uranium Demand, Supply, and Price, 1982, November 1982.

B.3 Impacts from Control-Caused Closures

As presented in Appendix A, some of the economic impact cases will result in mill closures caused by the tailings disposal cost. This section estimates the effect that these control-caused closures may have on the ability of the uranium industry to supply the market with the amount of uranium that is demanded. Control-caused closures (assumed in this analysis to be permanent) will reduce the amount of existing mill capacity which, in turn, could shift production to nonconventional sources or imports or require additional (from the baseline projection) new mills to be introduced.

With promulgation of these standards scheduled for the fall of 1983, we assume that all control-caused closures will take place in 1984. The initial response to any control-caused closures is for an equal amount of standby capacity to immediately reopen in 1984, the net effect being that the level of average standby capacity in 1984 is reduced by the amount of closures. As explained in Appendix A, the closure analysis is identically performed for both mills in operation and those on standby since the decision to operate in the future is basically the same regardless of whether the mill is currently operating or not. The closure analysis does not distinguish whether an estimated closure is for an operational or standby mill, and even if it did, the effect on industry capacity would be the same. In other words, a mill in operation closing and being replaced by a mill on standby reopening is the same as a mill on standby being permanently removed from the average standby capacity column.

With the 1984 level of average standby capacity reduced because of the closures, this reduces the amount of capacity that can be reopened in the future in response to increased demand or obsolete capacity. Consequently, the year when all the standby capacity is exhausted and new mill capacity begins may move up as a result of the closures. In this situation, any potential shortfall in conventional mill production due to the closures would be avoided by additional production at new mills. However, we have added a time constraint on the introduction of new mills which may allow this potential shortfall to occur. We have assumed that, in the case of control-caused closures, no new mill capacity beyond that projected in the baseline case can become operational before 1990. This constraint reflects the fact that it takes several years to bring a new facility on line, and that in the short-term, utilities will most likely seek other sources of supply - imports, nonconventional, or the secondary uranium market - if existing conventional capacity cannot deliver the amount demanded. If this new mill capacity constraint is reached, the shortfall occurs and we assume the demand is met by one of these other sources of supply. We do not specify which source of supply will result because, in all cases, no additional mill tailings at conventional mills will be generated, so that we are indifferent as to what the exact response will be. In 1990, this constraint in new mill capacity is removed, and if a shortfall is predicted, then additional (beyond the baseline) new mill capacity is introduced in that year to eliminate the shortfall.

The results of the mill closure analysis indicate that control-caused closures are expected in only 7 of the 25 economic impact cases. In six of the cases, one small model mill, or about 300 MT U_3O_8/year capacity, is estimated to close. In the seventh case, two small model mills, or about 600 MT U_3O_8/year capacity, are estimated to close. Tables B.7 and B.8 present the projections of conventional mill capacity and production for each of these two closure situations, respectively. As these tables indicate, the reduction (from the baseline) in the 1984 average standby capacity resulting from the control-caused closures is not large enough to create a shortfall so that there is no impact on the ability of the conventional mill sector to meet uranium demand. The introduction of new mill capacity still begins in 1992 as in the baseline projection. There is a slight shift in cumulative production (1983-2000) from existing mills to new mills in each case. In the one small mill closure case, about 2000 MT U_3O_8 production or 1 percent of the cumulative baseline production at existing mills is shifted to new mills. In the two small mill closure cases, approximately 4500 MT U_3O_8 production or 3 percent of the cumulative baseline production at existing mills is shifted to new mills.

Table B.7. Conventional Mill Capacity and Production Projections – Cases 9, 13, 32, 33, 35, 36 (Thousands of Metric Tons of U_3O_8)

	Conven. Demand	Obsolete Capacity	Closures		Additional Capacity		Avg. Capacity		Capacity Util. Rate	Production		
			Reg.	Mkt.	Reopened	New	Oper.	Standby		Total	Old	New
1983	7.5	0.7	0.0	1.0	0.0	0.0	12.4	5.0	.60	7.5	7.5	0.0
1984	6.3	0.6	0.3	1.4	0.3	0.0	10.5	6.1	.60	6.3	6.3	0.0
1985	7.3	0.5	0.0	0.0	1.2	0.0	11.2	4.9	.65	7.3	7.3	0.0
1986	7.8	0.5	0.0	0.0	1.3	0.0	11.9	3.6	.65	7.8	7.8	0.0
1987	6.7	0.6	0.0	1.1	0.0	0.0	10.3	4.7	.65	6.7	6.7	0.0
1988	7.4	0.5	0.0	0.0	0.8	0.0	10.6	3.9	.70	7.4	7.4	0.0
1989	7.6	0.5	0.0	0.0	0.7	0.0	10.8	3.2	.70	7.6	7.6	0.0
1990	9.5	0.5	0.0	0.0	2.4	0.0	12.7	0.8	.75	9.5	9.5	0.0
1991	9.2	0.6	0.0	0.0	0.2	0.0	12.3	0.6	.75	9.2	9.2	0.0
1992	10.2	0.6	0.0	0.0	0.6	1.3	13.6	0.0	.75	10.2	9.2	1.0
1993	10.3	0.6	0.0	0.0	0.0	0.7	13.7	0.0	.75	10.3	8.8	1.5
1994	10.0	0.6	0.0	0.0	0.0	0.3	13.3	0.0	.75	10.0	8.3	1.7
1995	10.5	0.6	0.0	0.0	0.0	1.3	14.0	0.0	.75	10.5	7.8	2.7
1996	10.0	0.7	0.0	0.0	0.0	0.0	13.3	0.0	.75	10.0	7.3	2.7
1997	9.3	0.6	0.0	0.3	0.0	0.0	12.4	0.3	.75	9.3	6.6	2.7
1998	9.7	0.6	0.0	0.0	0.3	0.8	12.9	0.0	.75	9.7	6.4	3.3
1999	10.2	0.6	0.0	0.0	0.0	1.3	13.6	0.0	.75	10.2	5.9	4.3
2000	11.3	0.6	0.0	0.0	0.0	2.1	15.1	0.0	.75	11.3	5.5	5.8

Table B.8. Conventional Mill Capacity and Production Projections - Case 37
(Thousands of Metric Tons of U_3O_8)

	Conven. Demand	Obsolete Capacity	Closures		Additional Capacity		Avg. Capacity		Capacity Util. Rate	Production		
			Reg.	Mkt.	Reopened	New	Oper.	Standby		Total	Old	New
1983	7.5	0.7	0.0	1.0	0.0	0.0	12.4	5.0	.60	7.5	7.5	0.0
1984	6.3	0.6	0.6	1.4	0.6	0.0	10.5	5.8	.60	6.3	6.3	0.0
1985	7.3	0.5	0.0	0.0	1.2	0.0	11.2	4.6	.65	7.3	7.3	0.0
1986	7.8	0.5	0.0	0.0	1.3	0.0	11.9	3.3	.65	7.8	7.8	0.0
1987	6.7	0.6	0.0	1.1	0.0	0.0	10.3	4.4	.65	6.7	6.7	0.0
1988	7.4	0.5	0.0	0.0	0.8	0.0	10.6	3.6	.70	7.4	7.4	0.0
1989	7.6	0.5	0.0	0.0	0.7	0.0	10.8	2.9	.70	7.6	7.6	0.0
1990	9.5	0.5	0.0	0.0	2.4	0.0	12.7	0.5	.75	9.5	9.5	0.0
1991	9.2	0.6	0.0	0.0	0.2	0.0	12.3	0.3	.75	9.2	9.2	0.0
1992	10.2	0.6	0.0	0.0	0.3	1.6	13.6	0.0	.75	10.2	9.0	1.2
1993	10.3	0.6	0.0	0.0	0.0	0.8	13.8	0.0	.75	10.3	8.5	1.8
1994	10.0	0.6	0.0	0.0	0.0	0.3	13.4	0.0	.75	10.1	8.0	2.0
1995	10.5	0.6	0.0	0.0	0.0	1.3	14.1	0.0	.75	10.6	7.6	3.0
1996	10.0	0.7	0.0	0.1	0.0	0.0	13.3	0.1	.75	10.0	7.0	3.0
1997	9.3	0.6	0.0	0.3	0.0	0.0	12.4	0.4	.75	9.3	6.3	3.0
1998	9.7	0.6	0.0	0.0	0.4	0.7	12.9	0.0	.75	9.7	6.1	3.6
1999	10.2	0.6	0.0	0.0	0.0	1.3	13.6	0.0	.75	10.2	5.6	4.6
2000	11.3	0.6	0.0	0.0	0.0	2.1	15.1	0.0	.75	11.3	5.2	6.1

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APPENDIX C

ANNUAL INDUSTRY DISPOSAL COSTS, BY ECONOMIC IMPACT CASE AND INDUSTRY CATEGORY, 1983-2000

TABLE C.1. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 1

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED 5%	TOTAL 10%
1983	0.0	0.0	0.0	0.0	0.0	0.0
1984	0.0	0.0	0.0	0.0	0.0	0.0
1985	0.0	0.0	0.0	0.0	0.0	0.0
1986	0.0	0.0	0.0	0.0	0.0	0.0
1987	0.0	0.0	0.0	0.0	0.0	0.0
1988	0.0	0.0	0.0	0.0	0.0	0.0
1989	0.0	0.0	0.0	0.0	0.0	0.0
1990	0.0	0.0	0.0	0.0	0.0	0.0
1991	0.0	0.0	0.0	0.0	0.0	0.0
1992	0.0	0.0	0.1	0.1	0.1	0.0
1993	0.0	0.0	0.2	0.2	0.1	0.1
1994	0.0	0.0	0.2	0.2	0.1	0.1
1995	0.0	0.0	0.4	0.4	0.2	0.1
1996	0.0	0.0	0.4	0.4	0.2	0.1
1997	0.0	0.0	0.4	0.4	0.2	0.1
1998	0.0	0.0	0.5	0.5	0.2	0.1
1999	0.0	0.0	0.7	0.7	0.3	0.1
2000	0.0	0.0	0.9	0.9	0.4	0.2
CUMULATIVE COST 1983-2000	0.0	0.0	3.9	3.9	1.9	0.9

TABLE C.2. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 2

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	31.1	0.8	0.0	31.8	30.3	28.9
1984	31.1	0.6	0.0	31.7	28.8	26.2
1985	31.1	0.7	0.0	31.8	27.5	23.9
1986	31.1	0.8	0.0	31.9	26.2	21.8
1987	31.1	0.7	0.0	31.8	24.9	19.7
1988	0.0	0.7	0.0	0.7	0.6	0.4
1989	0.0	0.8	0.0	0.8	0.5	0.4
1990	0.0	1.0	0.0	1.0	0.7	0.4
1991	0.0	0.9	0.0	0.9	0.6	0.4
1992	0.0	1.0	2.2	3.2	1.9	1.2
1993	0.0	0.9	3.7	4.6	2.7	1.6
1994	0.0	0.9	4.4	5.3	2.9	1.7
1995	0.0	0.8	7.3	8.1	4.3	2.3
1996	0.0	0.8	7.3	8.0	4.0	2.1
1997	0.0	0.7	7.3	7.9	3.8	1.9
1998	0.0	0.7	9.0	9.7	4.4	2.1
1999	0.0	0.6	11.9	12.5	5.5	2.5
2000	0.0	0.6	16.5	17.1	7.1	3.1
CUMULATIVE COST 1983-2000	155.4	13.8	69.5	238.7	176.7	140.7

TABLE C.3. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 3

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	50.5	1.0	0.0	51.5	49.1	46.8
1984	50.5	0.8	0.0	51.4	46.6	42.4
1985	50.5	1.0	0.0	51.5	44.5	38.7
1986	50.5	1.0	0.0	51.6	42.4	35.2
1987	50.5	0.9	0.0	51.4	40.3	31.9
1988	0.0	1.0	0.0	1.0	0.7	0.6
1989	0.0	1.0	0.0	1.0	0.7	0.5
1990	0.0	1.3	0.0	1.3	0.9	0.6
1991	0.0	1.2	0.0	1.2	0.8	0.5
1992	0.0	1.3	2.5	3.8	2.3	1.5
1993	0.0	1.2	4.3	5.5	3.2	1.9
1994	0.0	1.1	5.1	6.2	3.5	2.0
1995	0.0	1.1	8.4	9.5	5.0	2.7
1996	0.0	1.0	8.4	9.4	4.7	2.5
1997	0.0	0.9	8.4	9.3	4.5	2.2
1998	0.0	0.9	10.4	11.3	5.2	2.5
1999	0.0	0.8	13.7	14.6	6.4	2.9
2000	0.0	0.8	19.1	19.8	8.2	3.6
CUMULATIVE COST 1983-2000	252.6	18.3	80.4	351.3	269.0	219.0

TABLE C.4. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 4

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	67.6	1.2	0.0	68.8	65.5	62.6
1984	67.6	1.0	0.0	68.6	62.2	56.7
1985	67.6	1.1	0.0	68.8	59.4	51.7
1986	67.6	1.2	0.0	68.9	56.6	47.0
1987	67.6	1.0	0.0	68.7	53.8	42.6
1988	0.0	1.2	0.0	1.2	0.9	0.7
1989	0.0	1.2	0.0	1.2	0.8	0.6
1990	0.0	1.5	0.0	1.5	1.0	0.7
1991	0.0	1.4	0.0	1.4	0.9	0.6
1992	0.0	1.5	2.9	4.4	2.7	1.7
1993	0.0	1.4	5.0	6.4	3.7	2.2
1994	0.0	1.3	5.9	7.2	4.0	2.3
1995	0.0	1.3	9.7	10.9	5.8	3.2
1996	0.0	1.2	9.7	10.8	5.5	2.9
1997	0.0	1.1	9.7	10.7	5.2	2.6
1998	0.0	1.0	12.0	13.0	6.0	2.8
1999	0.0	1.0	15.8	16.8	7.3	3.3
2000	0.0	0.9	22.0	22.8	9.5	4.1
CUMULATIVE COST 1983-2000	338.2	21.4	92.5	452.1	350.9	288.3

TABLE C.5. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 5

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	30.3	3.0	0.0	33.3	31.7	30.3
1984	30.3	2.5	0.0	32.8	29.8	27.1
1985	30.3	2.9	0.0	33.2	28.7	25.0
1986	30.3	3.1	0.0	33.4	27.5	22.8
1987	30.3	2.7	0.0	33.0	25.9	20.5
1988	0.0	3.0	0.0	3.0	2.2	1.7
1989	0.0	3.0	0.0	3.0	2.2	1.6
1990	0.0	3.8	0.0	3.8	2.6	1.8
1991	0.0	3.7	0.0	3.7	2.4	1.6
1992	0.0	3.8	2.2	6.0	3.7	2.3
1993	0.0	3.6	3.7	7.3	4.3	2.6
1994	0.0	3.4	4.4	7.8	4.4	2.5
1995	0.0	3.2	7.3	10.5	5.6	3.0
1996	0.0	3.0	7.3	10.3	5.2	2.7
1997	0.0	2.7	7.3	10.0	4.8	2.4
1998	0.0	2.7	9.0	11.7	5.3	2.5
1999	0.0	2.5	11.9	14.4	6.3	2.8
2000	0.0	2.3	16.5	18.8	7.8	3.4
CUMULATIVE COST 1983-2000	151.6	55.1	69.5	276.1	200.3	156.6

TABLE C.6. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 6

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	50.5	3.4	0.0	53.9	51.3	49.0
1984	50.5	2.8	0.0	53.4	48.4	44.1
1985	50.5	3.3	0.0	53.8	46.5	40.4
1986	50.5	3.5	0.0	54.1	44.5	36.9
1987	50.5	3.0	0.0	53.6	42.0	33.3
1988	0.0	3.4	0.0	3.4	2.5	1.9
1989	0.0	3.4	0.0	3.4	2.4	1.8
1990	0.0	4.3	0.0	4.3	2.9	2.0
1991	0.0	4.2	0.0	4.2	2.7	1.8
1992	0.0	4.3	2.6	6.9	4.2	2.7
1993	0.0	4.1	4.5	8.6	5.0	3.0
1994	0.0	3.8	5.3	9.1	5.1	2.9
1995	0.0	3.6	8.7	12.3	6.5	3.6
1996	0.0	3.4	8.7	12.1	6.1	3.2
1997	0.0	3.1	8.7	11.8	5.7	2.8
1998	0.0	3.0	10.8	13.8	6.3	3.0
1999	0.0	2.8	14.3	17.0	7.4	3.4
2000	0.0	2.6	19.8	22.4	9.3	4.0
CUMULATIVE COST 1983-2000	252.7	62.0	83.4	398.1	299.0	239.7

TABLE C.7. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 7

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	68.7	3.7	0.0	72.4	69.0	65.8
1984	68.7	3.1	0.0	71.8	65.1	59.3
1985	68.7	3.6	0.0	72.3	62.5	54.3
1986	68.7	3.9	0.0	72.6	59.7	49.6
1987	68.7	3.3	0.0	72.0	56.4	44.7
1988	0.0	3.7	0.0	3.7	2.8	2.1
1989	0.0	3.8	0.0	3.8	2.7	1.9
1990	0.0	4.8	0.0	4.8	3.2	2.2
1991	0.0	4.6	0.0	4.6	3.0	2.0
1992	0.0	4.7	3.0	7.8	4.8	3.0
1993	0.0	4.5	5.1	9.6	5.6	3.4
1994	0.0	4.3	6.0	10.3	5.7	3.3
1995	0.0	4.0	10.0	14.0	7.4	4.1
1996	0.0	3.8	10.0	13.8	6.9	3.6
1997	0.0	3.4	10.0	13.4	6.4	3.2
1998	0.0	3.3	12.4	15.7	7.2	3.4
1999	0.0	3.1	16.3	19.4	8.5	3.8
2000	0.0	2.9	22.7	25.5	10.6	4.6
CUMULATIVE COST 1983-2000	343.3	68.7	95.5	507.5	387.6	314.4

TABLE C.8. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 8

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	88.7	4.2	0.0	92.8	88.4	84.4
1984	88.7	3.5	0.0	92.2	83.6	76.2
1985	88.7	4.1	0.0	92.7	80.1	69.7
1986	88.7	4.3	0.0	93.0	76.5	63.5
1987	88.7	3.7	0.0	92.4	72.4	57.4
1988	0.0	4.1	0.0	4.1	3.1	2.3
1989	0.0	4.2	0.0	4.2	3.0	2.2
1990	0.0	5.3	0.0	5.3	3.6	2.5
1991	0.0	5.2	0.0	5.2	3.3	2.2
1992	0.0	5.3	3.4	8.7	5.4	3.4
1993	0.0	5.0	5.8	10.9	6.4	3.8
1994	0.0	4.8	6.9	11.6	6.5	3.7
1995	0.0	4.5	11.3	15.8	8.4	4.6
1996	0.0	4.2	11.3	15.6	7.9	4.1
1997	0.0	3.8	11.3	15.2	7.3	3.6
1998	0.0	3.7	14.1	17.8	8.2	3.9
1999	0.0	3.5	18.6	22.0	9.6	4.4
2000	0.0	3.2	25.8	29.0	12.0	5.2
CUMULATIVE COST 1983-2000	443.3	76.6	108.6	628.5	485.6	396.9

TABLE C.9. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 9

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED 5%	TOTAL 10%
1983	106.5	4.6	0.0	111.1	105.8	101.0
1984	106.5	3.9	0.0	110.4	100.1	91.2
1985	106.5	4.5	0.0	111.0	95.9	83.4
1986	106.5	4.8	0.0	111.3	91.6	76.0
1987	106.5	4.1	0.0	110.6	86.7	68.7
1988	0.0	4.6	0.0	4.6	3.4	2.6
1989	0.0	4.6	0.0	4.6	3.3	2.4
1990	0.0	5.9	0.0	5.9	4.0	2.7
1991	0.0	5.7	0.0	5.7	3.7	2.4
1992	0.0	5.7	5.0	10.7	6.5	4.1
1993	0.0	5.4	7.7	13.0	7.6	4.6
1994	0.0	5.1	8.8	13.9	7.7	4.4
1995	0.0	4.8	13.8	18.6	9.9	5.[illegible]
1996	0.0	4.5	13.8	18.3	9.2	4.8
1997	0.0	4.1	13.8	17.9	8.6	4.3
1998	0.0	3.9	16.9	20.8	9.5	4.5
1999	0.0	3.7	21.8	25.5	11.1	5.0
2000	0.0	3.4	29.9	33.2	13.8	6.0
CUMULATIVE COST 1983-2000	532.7	83.0	131.4	747.0	578.5	473.6

TABLE C.10. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 10

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL 5%	DISCOUNTED TOTAL 10%
1983	50.5	3.4	0.0	53.9	51.3	49.0
1984	50.5	2.8	0.0	53.4	48.4	44.1
1985	50.5	3.3	0.0	53.8	46.5	40.4
1986	50.5	3.5	0.0	54.1	44.5	36.9
1987	50.5	3.0	0.0	53.6	42.0	33.3
1988	0.0	3.4	0.0	3.4	2.5	1.9
1989	0.0	3.4	0.0	3.4	2.4	1.8
1990	0.0	4.3	0.0	4.3	2.9	2.0
1991	0.0	4.2	0.0	4.2	2.7	1.8
1992	0.0	4.3	3.9	8.2	5.0	3.1
1993	0.0	4.1	6.6	10.7	6.2	3.7
1994	0.0	3.8	7.8	11.6	6.5	3.7
1995	0.0	3.6	12.8	16.4	8.7	4.8
1996	0.0	3.4	12.8	16.2	8.2	4.3
1997	0.0	3.1	12.8	15.9	7.6	3.8
1998	0.0	3.0	15.9	18.9	8.7	4.1
1999	0.0	2.8	20.9	23.7	10.4	4.7
2000	0.0	2.6	29.1	31.7	13.2	5.7
CUMULATIVE COST 1983-2000	252.7	62.0	122.5	437.2	317.6	249.1

TABLE C.11. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 11

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	68.7	3.7	0.0	72.4	69.0	65.8
1984	68.7	3.1	0.0	71.8	65.1	59.3
1985	68.7	3.6	0.0	72.3	62.5	54.3
1986	68.7	3.9	0.0	72.6	59.7	49.6
1987	68.7	3.3	0.0	72.0	56.4	44.7
1988	0.0	3.7	0.0	3.7	2.8	2.1
1989	0.0	3.8	0.0	3.8	2.7	1.9
1990	0.0	4.8	0.0	4.8	3.2	2.2
1991	0.0	4.6	0.0	4.6	3.0	2.0
1992	0.0	4.7	4.2	8.9	5.5	3.4
1993	0.0	4.5	7.1	11.6	6.8	4.1
1994	0.0	4.3	8.4	12.6	7.0	4.0
1995	0.0	4.0	13.8	17.8	9.5	5.2
1996	0.0	3.8	13.8	17.6	8.9	4.6
1997	0.0	3.4	13.8	17.2	8.3	4.1
1998	0.0	3.3	17.2	20.5	9.4	4.5
1999	0.0	3.1	22.6	25.7	11.2	5.1
2000	0.0	2.9	31.4	34.2	14.2	6.2
CUMULATIVE COST 1983-2000	343.3	68.7	132.2	544.2	405.1	323.1

TABLE C.12. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 12

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	88.7	4.2	0.0	92.8	88.4	84.4
1984	88.7	3.5	0.0	92.2	83.6	76.2
1985	88.7	4.1	0.0	92.7	80.1	69.7
1986	88.7	4.3	0.0	93.0	76.5	63.5
1987	88.7	3.7	0.0	92.4	72.4	57.4
1988	0.0	4.1	0.0	4.1	3.1	2.3
1989	0.0	4.2	0.0	4.2	3.0	2.2
1990	0.0	5.3	0.0	5.3	3.6	2.5
1991	0.0	5.2	0.0	5.2	3.3	2.2
1992	0.0	5.3	4.6	9.9	6.1	3.8
1993	0.0	5.0	7.8	12.8	7.5	4.5
1994	0.0	4.8	9.1	13.9	7.7	4.4
1995	0.0	4.5	15.1	19.6	10.4	5.7
1996	0.0	4.2	15.1	19.3	9.7	5.1
1997	0.0	3.8	15.1	18.9	9.1	4.5
1998	0.0	3.7	18.7	22.4	10.3	4.9
1999	0.0	3.5	24.7	28.1	12.3	5.6
2000	0.0	3.2	34.3	37.4	15.6	6.7
CUMULATIVE COST 1983-2000	443.3	76.6	144.4	664.3	502.6	405.5

TABLE C.13. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 13

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	106.5	4.6	0.0	111.1	105.8	101.0
1984	106.5	3.9	0.0	110.4	100.1	91.2
1985	106.5	4.5	0.0	111.0	95.9	83.4
1986	106.5	4.8	0.0	111.3	91.6	76.0
1987	106.5	4.1	0.0	110.6	86.7	68.7
1988	0.0	4.6	0.0	4.6	3.4	2.6
1989	0.0	4.6	0.0	4.6	3.3	2.4
1990	0.0	5.9	0.0	5.9	4.0	2.7
1991	0.0	5.7	0.0	5.7	3.7	2.4
1992	0.0	5.7	6.4	12.1	7.4	4.7
1993	0.0	5.4	9.8	15.2	8.9	5.3
1994	0.0	5.1	11.3	16.4	9.1	5.2
1995	0.0	4.8	17.7	22.5	11.9	6.5
1996	0.0	4.5	17.7	22.2	11.2	5.8
1997	0.0	4.1	17.7	21.8	10.5	5.2
1998	0.0	3.9	21.6	25.6	11.7	5.6
1999	0.0	3.7	28.0	31.7	13.8	6.3
2000	0.0	3.4	38.3	41.7	17.3	7.5
CUMULATIVE COST 1983-2000	532.7	83.0	168.6	784.2	596.3	482.6

TABLE C.14. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 26

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	31.1	21.9	0.0	52.9	50.4	48.1
1984	31.1	18.4	0.0	49.5	44.9	40.9
1985	31.1	21.3	0.0	52.3	45.2	39.3
1986	31.1	22.7	0.0	53.8	44.3	36.8
1987	31.1	19.6	0.0	50.7	39.7	31.5
1988	0.0	21.7	0.0	21.7	16.2	12.3
1989	0.0	22.1	0.0	22.1	15.7	11.4
1990	0.0	27.9	0.0	27.9	18.9	13.0
1991	0.0	27.0	0.0	27.0	17.4	11.5
1992	0.0	27.7	2.2	29.9	18.4	11.5
1993	0.0	26.3	3.7	30.1	17.6	10.5
1994	0.0	24.9	4.4	29.3	16.3	9.3
1995	0.0	23.5	7.3	30.8	16.3	8.9
1996	0.0	22.1	7.3	29.3	14.8	7.7
1997	0.0	20.0	7.3	27.3	13.1	6.5
1998	0.0	19.4	9.0	28.4	13.0	6.2
1999	0.0	18.1	11.9	30.0	13.1	5.9
2000	0.0	16.7	16.5	33.2	13.8	6.0
CUMULATIVE COST 1983-2000	155.4	401.4	69.5	626.2	429.1	317.3

TABLE C.15. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 27

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	50.5	25.3	0.0	75.8	72.2	68.9
1984	50.5	21.3	0.0	71.8	65.1	59.3
1985	50.5	24.6	0.0	75.1	64.9	56.4
1986	50.5	26.3	0.0	76.8	63.2	52.5
1987	50.5	22.7	0.0	73.2	57.3	45.4
1988	0.0	25.1	0.0	25.1	18.8	14.2
1989	0.0	25.6	0.0	25.6	18.2	13.2
1990	0.0	32.3	0.0	32.3	21.8	15.1
1991	0.0	31.3	0.0	31.3	20.2	13.3
1992	0.0	32.1	2.5	34.6	21.3	13.4
1993	0.0	30.5	4.3	34.8	20.3	12.2
1994	0.0	28.8	5.1	33.9	18.9	10.8
1995	0.0	27.2	8.4	35.6	18.9	10.3
1996	0.0	25.6	8.4	33.9	17.1	8.9
1997	0.0	23.2	8.4	31.6	15.2	7.6
1998	0.0	22.5	10.4	32.9	15.1	7.2
1999	0.0	20.9	13.7	34.7	15.1	6.9
2000	0.0	19.3	19.1	38.4	15.9	6.9
CUMULATIVE COST 1983-2000	252.6	464.5	80.4	797.5	559.6	422.4

TABLE C.16. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 28

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED 5%	TOTAL 10%
1983	67.6	29.1	0.0	96.8	92.2	88.0
1984	67.6	24.5	0.0	92.1	83.6	76.1
1985	67.6	28.3	0.0	96.0	82.9	72.1
1986	67.6	30.3	0.0	97.9	80.6	66.9
1987	67.6	26.1	0.0	93.7	73.4	58.2
1988	0.0	28.9	0.0	28.9	21.6	16.3
1989	0.0	29.5	0.0	29.5	21.0	15.1
1990	0.0	37.1	0.0	37.1	25.1	17.3
1991	0.0	36.0	0.0	36.0	23.2	15.3
1992	0.0	36.9	2.9	39.9	24.5	15.4
1993	0.0	35.1	5.0	40.0	23.4	14.0
1994	0.0	33.2	5.9	39.0	21.7	12.4
1995	0.0	31.3	9.7	41.0	21.7	11.9
1996	0.0	29.4	9.7	39.1	19.7	10.3
1997	0.0	26.7	9.7	36.4	17.5	8.7
1998	0.0	25.9	12.0	37.9	17.3	8.2
1999	0.0	24.1	15.8	39.9	17.4	7.9
2000	0.0	22.2	22.0	44.2	18.4	7.9
CUMULATIVE COST 1983-2000	338.2	534.6	92.5	965.3	685.2	522.1

TABLE C.17. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 29

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	30.3	21.9	0.0	52.2	49.7	47.4
1984	30.3	18.4	0.0	48.7	44.2	40.2
1985	30.3	21.3	0.0	51.6	44.6	38.8
1986	30.3	22.7	0.0	53.1	43.7	36.2
1987	30.3	19.6	0.0	49.9	39.1	31.0
1988	0.0	21.7	0.0	21.7	16.2	12.3
1989	0.0	22.1	0.0	22.1	15.7	11.4
1990	0.0	27.9	0.0	27.9	18.9	13.0
1991	0.0	27.0	0.0	27.0	17.4	11.5
1992	0.0	27.7	2.2	29.9	18.4	11.5
1993	0.0	26.3	3.7	30.1	17.6	10.5
1994	0.0	24.9	4.4	29.3	16.3	9.3
1995	0.0	23.5	7.3	30.8	16.3	8.9
1996	0.0	22.1	7.3	29.3	14.8	7.7
1997	0.0	20.0	7.3	27.3	13.1	6.5
1998	0.0	19.4	9.0	28.4	13.0	6.2
1999	0.0	18.1	11.9	30.0	13.1	5.9
2000	0.0	16.7	16.5	33.2	13.8	6.0
CUMULATIVE COST 1983-2000	151.6	401.4	69.5	622.4	425.8	314.4

TABLE C.18. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 30

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL 5%	DISCOUNTED TOTAL 10%
1983	50.5	26.3	0.0	76.8	73.1	69.8
1984	50.5	22.1	0.0	72.6	65.9	60.0
1985	50.5	25.5	0.0	76.1	65.7	57.2
1986	50.5	27.3	0.0	77.8	64.0	53.2
1987	50.5	23.5	0.0	74.0	58.0	46.0
1988	0.0	26.1	0.0	26.1	19.5	14.7
1989	0.0	26.6	0.0	26.6	18.9	13.6
1990	0.0	33.5	0.0	33.5	22.7	15.6
1991	0.0	32.4	0.0	32.4	20.9	13.8
1992	0.0	33.3	2.6	35.9	22.1	13.9
1993	0.0	31.6	4.5	36.1	21.1	12.7
1994	0.0	29.9	5.3	35.2	19.6	11.2
1995	0.0	28.3	8.7	37.0	19.6	10.7
1996	0.0	26.5	8.7	35.2	17.8	9.3
1997	0.0	24.1	8.7	32.8	15.8	7.8
1998	0.0	23.3	10.8	34.1	15.6	7.4
1999	0.0	21.7	14.3	36.0	15.7	7.1
2000	0.0	20.0	19.8	39.8	16.5	7.2
CUMULATIVE COST 1983-2000	252.7	482.0	83.4	818.1	572.5	431.1

TABLE C.19. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 31

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	68.7	30.1	0.0	98.7	94.0	89.8
1984	68.7	25.3	0.0	93.9	85.2	77.6
1985	68.7	29.2	0.0	97.9	84.6	73.6
1986	68.7	31.3	0.0	99.9	82.2	68.3
1987	68.7	26.9	0.0	95.6	74.9	59.4
1988	0.0	29.9	0.0	29.9	22.3	16.9
1989	0.0	30.5	0.0	30.5	21.6	15.6
1990	0.0	38.4	0.0	38.4	26.0	17.9
1991	0.0	37.2	0.0	37.2	24.0	15.8
1992	0.0	38.1	3.0	41.2	25.3	15.9
1993	0.0	36.2	5.1	41.3	24.2	14.5
1994	0.0	34.3	6.0	40.3	22.4	12.8
1995	0.0	32.4	10.0	42.3	22.5	12.3
1996	0.0	30.4	10.0	40.4	20.4	10.6
1997	0.0	27.6	10.0	37.5	18.1	9.0
1998	0.0	26.7	12.4	39.1	17.9	8.5
1999	0.0	24.9	16.3	41.2	18.0	8.2
2000	0.0	22.9	22.7	45.6	19.0	8.2
CUMULATIVE COST 1983-2000	343.3	552.1	95.5	991.0	702.4	534.7

TABLE C.20. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 32

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	88.7	34.2	0.0	122.8	117.0	111.7
1984	88.7	28.7	0.0	117.4	106.5	97.0
1985	88.7	33.2	0.0	121.9	105.3	91.6
1986	88.7	35.5	0.0	124.2	102.2	84.8
1987	88.7	30.6	0.0	119.3	93.4	74.1
1988	0.0	34.0	0.0	34.0	25.4	19.2
1989	0.0	34.6	0.0	34.6	24.6	17.8
1990	0.0	43.6	0.0	43.6	29.5	20.3
1991	0.0	42.2	0.0	42.2	27.2	17.9
1992	0.0	42.3	4.5	46.8	28.7	18.0
1993	0.0	40.1	6.9	47.0	27.5	16.5
1994	0.0	37.9	7.9	45.8	25.5	14.6
1995	0.0	35.7	12.4	48.1	25.5	13.9
1996	0.0	33.5	12.4	45.8	23.2	12.1
1997	0.0	30.3	12.4	42.7	20.5	10.2
1998	0.0	29.3	15.1	44.4	20.4	9.7
1999	0.0	27.2	19.6	46.8	20.4	9.3
2000	0.0	25.0	26.8	51.8	21.5	9.3
CUMULATIVE COST 1983-2000	443.3	618.1	117.9	1179.2	844.3	647.9

TABLE C.21. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 33

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	106.5	38.1	0.0	144.6	137.8	131.5
1984	106.5	32.0	0.0	138.6	125.7	114.5
1985	106.5	37.0	0.0	143.6	124.0	107.9
1986	106.5	39.6	0.0	146.2	120.2	99.8
1987	106.5	34.1	0.0	140.6	110.2	87.3
1988	0.0	37.9	0.0	37.9	28.3	21.4
1989	0.0	38.6	0.0	38.6	27.4	19.8
1990	0.0	48.6	0.0	48.6	32.9	22.7
1991	0.0	47.1	0.0	47.1	30.3	20.0
1992	0.0	47.1	5.0	52.1	32.0	20.1
1993	0.0	44.7	7.7	52.3	30.6	18.3
1994	0.0	42.2	8.8	51.0	28.4	16.3
1995	0.0	39.8	13.8	53.6	28.4	15.5
1996	0.0	37.3	13.8	51.1	25.8	13.5
1997	0.0	33.8	13.8	47.5	22.9	11.4
1998	0.0	32.7	16.9	49.5	22.7	10.8
1999	0.0	30.3	21.8	52.2	22.8	10.3
2000	0.0	27.9	29.9	57.8	24.0	10.4
CUMULATIVE COST 1983-2000	532.7	688.8	131.4	1352.9	974.4	751.4

TABLE C.22. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 34

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	50.5	38.6	0.0	89.1	84.9	81.0
1984	50.5	32.4	0.0	83.0	75.3	68.6
1985	50.5	37.5	0.0	88.0	76.1	66.2
1986	50.5	40.1	0.0	90.7	74.6	61.9
1987	50.5	34.5	0.0	85.1	66.7	52.8
1988	0.0	38.3	0.0	38.3	28.6	21.6
1989	0.0	39.1	0.0	39.1	27.8	20.0
1990	0.0	49.2	0.0	49.2	33.3	23.0
1991	0.0	47.7	0.0	47.7	30.7	20.2
1992	0.0	48.9	3.9	52.8	32.4	20.4
1993	0.0	46.4	6.6	53.0	31.0	18.6
1994	0.0	43.9	7.8	51.7	28.8	16.5
1995	0.0	41.5	12.8	54.3	28.8	15.7
1996	0.0	39.0	12.8	51.8	26.1	13.6
1997	0.0	35.4	12.8	48.2	23.2	11.5
1998	0.0	34.3	15.9	50.2	23.0	10.9
1999	0.0	31.9	20.9	52.8	23.1	10.5
2000	0.0	29.4	29.1	58.5	24.3	10.5
CUMULATIVE COST 1983-2000	252.7	708.1	122.5	1083.4	738.5	543.5

TABLE C.23. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 35

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED 5%	TOTAL 10%
1983	68.7	41.6	0.0	110.3	105.0	100.3
1984	68.7	35.0	0.0	103.7	94.0	85.7
1985	68.7	40.5	0.0	109.1	94.3	82.0
1986	68.7	43.3	0.0	112.0	92.1	76.5
1987	68.7	37.3	0.0	105.9	83.0	65.8
1988	0.0	41.4	0.0	41.4	30.9	23.4
1989	0.0	42.2	0.0	42.2	30.0	21.6
1990	0.0	53.1	0.0	53.1	35.9	24.8
1991	0.0	51.4	0.0	51.4	33.2	21.8
1992	0.0	51.5	5.4	56.9	35.0	22.0
1993	0.0	48.8	8.4	57.2	33.4	20.0
1994	0.0	46.1	9.6	55.8	31.1	17.8
1995	0.0	43.5	15.1	58.6	31.1	17.0
1996	0.0	40.8	15.1	55.8	[illegible]8.2	14.7
1997	0.0	36.9	15.1	52.0	25.0	12.4
1998	0.0	35.7	18.4	54.1	24.8	11.8
1999	0.0	33.2	23.9	57.0	24.9	11.3
2000	0.0	30.5	32.6	63.1	26.2	11.4
CUMULATIVE COST 1983-2000	343.3	752.7	143.5	1239.6	858.0	640.0

TABLE C.24. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 36

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	88.7	45.5	0.0	134.1	127.7	121.9
1984	88.7	38.2	0.0	126.9	115.1	104.8
1985	88.7	44.2	0.0	132.9	114.8	99.8
1986	88.7	47.3	0.0	135.9	111.8	92.8
1987	88.7	40.7	0.0	129.3	101.3	80.3
1988	0.0	45.2	0.0	45.2	33.7	25.5
1989	0.0	46.0	0.0	46.0	32.7	23.6
1990	0.0	58.0	0.0	58.0	39.2	27.0
1991	0.0	56.2	0.0	56.2	36.2	23.8
1992	0.0	56.2	5.9	62.2	38.2	24.0
1993	0.0	53.3	9.1	62.4	36.5	21.9
1994	0.0	50.4	10.5	60.9	33.9	19.4
1995	0.0	47.5	16.4	64.0	33.9	18.5
1996	0.0	44.5	16.4	61.0	30.8	16.1
1997	0.0	40.3	16.4	56.7	27.3	13.6
1998	0.0	39.0	20.1	59.1	27.1	12.9
1999	0.0	36.2	26.0	62.2	27.2	12.3
2000	0.0	33.3	35.6	68.9	28.6	12.4
CUMULATIVE COST 1983-2000	443.3	821.8	156.7	1421.8	996.0	750.7

TABLE C.25. ANNUAL FLOWS OF INDUSTRY DISPOSAL COSTS, CASE 37

(MILLIONS OF 1983 DOLLARS)

	EXISTING TAILINGS	FUTURE TAILINGS EXISTING MILLS	FUTURE TAILINGS NEW MILLS	TOTAL COST	DISCOUNTED TOTAL	
					5%	10%
1983	106.5	48.9	0.0	155.4	148.0	141.3
1984	106.5	41.1	0.0	147.6	133.9	122.0
1985	106.5	47.5	0.0	154.1	133.1	115.8
1986	106.5	50.8	0.0	157.4	129.5	107.5
1987	106.5	43.8	0.0	150.3	117.8	93.3
1988	0.0	48.6	0.0	48.6	36.3	27.4
1989	0.0	49.5	0.0	49.5	35.2	25.4
1990	0.0	62.4	0.0	62.4	42.2	29.1
1991	0.0	60.4	0.0	60.4	38.9	25.6
1992	0.0	59.0	7.9	66.8	41.0	25.8
1993	0.0	55.8	11.8	67.6	39.5	23.7
1994	0.0	52.7	13.3	65.9	36.7	21.0
1995	0.0	49.6	19.7	69.2	36.7	20.0
1996	0.0	45.8	19.7	65.5	33.1	17.2
1997	0.0	41.3	19.7	60.9	29.3	14.6
1998	0.0	39.9	23.6	63.5	29.1	13.8
1999	0.0	36.9	30.0	66.9	29.2	13.2
2000	0.0	33.7	40.3	74.0	30.8	13.3
CUMULATIVE COST 1983-2000	532.7	867.6	185.8	1586.1	1120.3	850.2

Appendix D

Regulatory Flexibility Act Certification

The proposed standards for uranium mill tailings at active sites will not have a significant impact on a substantial number of small entities. The basis for this finding is that of the 27 licensed uranium mills, only one qualifies as a small entity, and this mill will not be impacted by the standards. Almost all the mills are owned by large corporations. Table D.1 lists each of the mills, the operating company, the parent corporation of the operator, and the employment of the parent corporation.

Based on the Small Business Administration's generic small entity definition of 500 employees, four of the parent corporations could qualify as small businesses. However, for the reasons explained below, we have determined that three of the mills owned by these companies are not small entities, while the fourth will not be affected by the standards.

American Nuclear Corporation - This company is a small business based on the SBA generic definition since it has only 125 employees. American Nuclear is a partner with Federal Resources Corporation, a company with 600 employees, in the ownership of the uranium mill in Gas Hills, Wyoming. The Tennessee Valley Authority, which has leased the mill from Federal-American Partners since 1973, has agreed in principal to buy the mill and the uranium properties in the area. According to the Regulatory Flexibility Act, a small business is one which is independently owned and operated. Since this mill is not independently owned by a small business, it is not a small entity.

Reserve Oil and Minerals Corporation - This company is a small business since it only has a handful of employees. However, since it is a partner with the Standard Oil Company of Ohio in the Seboyeta, New Mexico, mill, the mill is not a small entity.

Energy Fuels Nuclear - This privately-held company has 450 employees and owns about 60 percent of the Blanding, Utah, uranium mill. Two Swiss utilities own the remaining interest in the mill (Engineering and Mining Journal, November 1978, p. 125). Union Carbide is currently negotiating with Energy Fuels Nuclear to buy a majority interest in the mill. Since the mill is not independently owned, it is not a small entity.

Bokum Resources Corporation - This company is in a state of bankruptcy, and only a skeleton staff of employees exists. They are currently in litigation with a utility which has contributed to the bankruptcy. Since the mill at Marquez, New Mexico, has never operated and has no plans to operate for several years, there are no mill tailings and, therefore, no control costs to be incurred by this company. Therefore, the proposed standards will have no impact on this company.

Table D.1. Ownership of Licensed Uranium Mills

Uranium Mill Location	Mill Operator	Parent Corporation	Employment of Parent Corporation (Thousands)
Canon City, CO	Cotter Corp.	Commonwealth Edison	16
Uravan, CO	Union Carbide Corp.	Union Carbide Corp.	101
Seboyeta, NM	Sohio-Reserve	The Standard Oil Co. (Ohio)	23
		Reserve Oil & Minerals Corp.	< 1
Church Rock, NM	United Nuclear Corp.	UNC Resources, Inc.	5
Bluewater, NM	Anaconda	Atlantic Richfield Co.	53
Ambrosia Lake, NM	Kerr-McGee Nuclear Corp.	Kerr-McGee Corp.	11
Milan, NM	Homestake Mining Co.	Homestake Mining Co.	2
Marquez, NM	Bokum Resources Corp.	Bokum Resources Corp.	< 1
Edgemont, SD	Tennessee Valley Authority	U.S. Government	--
Panna Maria, TX	Chevron	Standard Oil of California	40
Falls City, TX	Conoco-Pioneer	Conoco, Inc.[a]	42
		Pioneer Corp.	3
Ray Point, TX	Exxon Corp.	Exxon Corp.	177
Blanding, UT	Energy Fuels Nuclear	Energy Fuels Nuclear[b]	< 1
La Sal, UT	Rio Algom Ltd.	Rio Algom Ltd.	7
Moab, UT	Atlas Corp.	Atlas Corp.	2
Hanksville, UT	Plateau Resources, Ltd.	Consumers Power Co.	12
Ford, WA	Dawn Mining Co.	Newmont Mining Corp.	12
Wellpinit, WA	Western Nuclear	Phelps Dodge Corp.	15
Gas Hills, WY	Federal-American Partners	Federal Resources Corp.[c]	< 1
		American Nuclear Corp.	< 1
Gas Hills, WY	Pathfinder Mines Corp.	General Electric[d]	402
Powder River, WY	Rocky Mountain Energy/ Mono Power	Union Pacific Corp.	33
		Southern California Edison Co.	14
Powder River, WY	Exxon Corp.	Exxon Corp.	177
Jeffrey City, WY	Western Nuclear Corp.	Phelps Dodge Corp.	15
Gas Hills, WY	Union Carbide Corp.	Union Carbide Corp.	101
Shirley Basin, WY	Pathfinder Mines Corp.	General Electric[d]	402
Shirley Basin, WY	Petrotomics Co.	Getty Oil Co.	17
Red Desert, WY	Minerals Exploration Co.	Union Oil Co.	17

(a)Conoco and Dupont merged in 1981.

(b)The Blanding mill is owned 60 percent by Energy Fuels Nuclear, and the remainder is owned by two Swiss utilities. Union Carbide is currently negotiating with Energy Fuels Nuclear to buy a majority interest in the mill.

(c)The Tennessee Valley Authority has agreed in principle to buy the mill from Federal-American Partners.

(d)General Electric has sold 80 percent of its interest in their uranium mills to the French company, Cogema.

TECHNICAL REPORT DATA

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16. ABSTRACT

The Environmental Protection Agency has promulgated health and environmental protection standards for control of uranium and thorium tailings during ore processing operations and for final disposal. These standards apply to tailings licensed by the U.S. Nuclear Regulatory Commission and the States under Title II of the Uranium Mill Tailings Radiation Control Act of 1978 (Public Law 95-604). This Regulatory Impact Analysis examines the costs, benefits, and economic impacts of alternative standards and presents the rationale for the selection of the final standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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